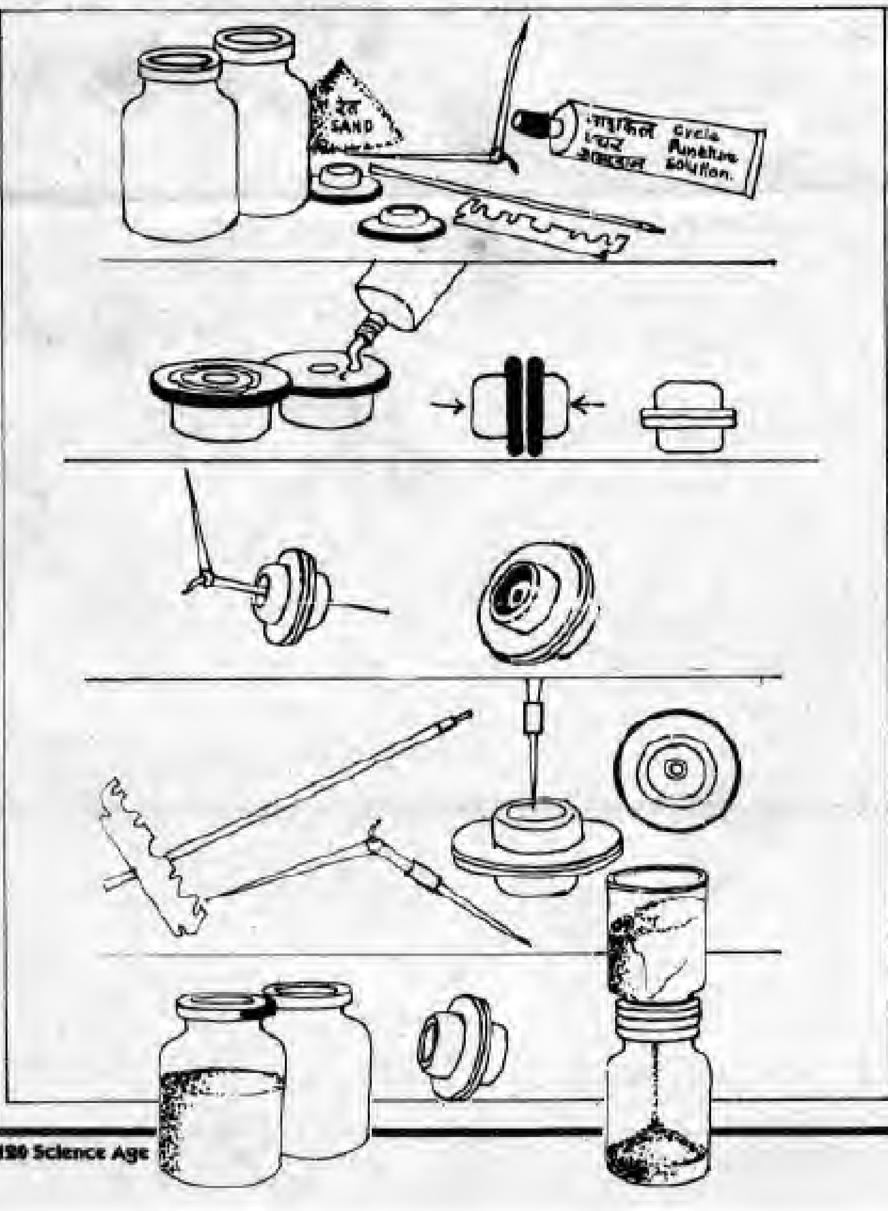
Tick! trick! trickle!

EVEN IF you own a sleek electronic wrist watch, the innate simplicity of a sand hour glass might charm you. For despite the neat and sophisticated gadgetry of the electronic watch — what with day, date, alarm, stopwatch, calculator and what not all stacked in a plastic sheath, it is still mystifying. Its like a black box, the exterior giving no clues to the working of the innards. And what if it conks out? Well, you can't do a thing apart from gaping at this marvel of modern technology with bemused amazement. You'll have to take it to a "specialist" — an electronic whiz kid for repairs. And you'll discover to your dismay that the cost of "repairs" is more than the cost of the actual tick-tock (sorry, these electronic ones are born heartless).

How about making a sand hour glass of your own? It's very simple and easy to make one, and furthermore, it would'nt cost you anything, for all you'll require are two used injection bottles, on old ball pen refill, cycle puncture repair solution, a needle, and of course sand. You'll enjoy making it. But once you've made it I can promise you fun in only small leaps — of just one minute each (and not in hours and days) for what you have made is a one-minute sand hour glass.

Sand hour glasses are more archaic than even vintage grandfather clocks. But like windmills of a bygone age, they still retain a charm because of their utter simplicity of conception. For instance, whereas you might not have the "pulse" of the digital electronic clocks, you can actually see time slip by through the transparent belly of the sand hour glass.



Soak two used injection bottles in water. After a while, when the glue has loosened, remove the labels. Clean and dry the injection bottles and their rubber caps.

Apply cycle puncture repair solution on the flat sides of the two injection bottle caps, and stick them back-to-back. Make a hole through the centre of these caps with the help of a babool thorn, or a needle (the point of the dividers or the compass of your geometry box will serve adequately). Insert a small (about half a centimetre long) piece of used plastic ball pen refill tube in the hole between the rubber caps. Ensure that the ball pen tube does not jut out and is flush with the trough levels of the rubber caps. The piece of refill provides a smooth and uniform bore for the sand to slip through.

Now fill fine dry sand in one of the injection bottles. If the sand is coarse, sieve it using a suitable piece of cloth. Sea sand is excellent. Assemble the rubber caps and the empty injection bottle on top. The final assembly resembles a dumbell of sorts. On inverting, sand from the top bottle trickles down into the lower bottle through the "neck" of the ball pen refill tube. Time your sand hour glass with the help of an actual clock adjusting the amount of sand to give a round figure in full minutes. With a bit of care you can have your sand hour glass measure a minute with an accuracy of plus or minus two seconds.

This sand hour glass provides a handy reference for one minute. Village health workers could use it for counting the pulse beat of patients in one minute. What are the things you could do in a minute? Now you can count with a sand-hour glass how many times you breathe in one minute, how many steps you normally walk in one minute, how many oscillations a pendulum (a stone tied to a string) makes in one minute and how the number of oscillations per minute varies with the length of the string. And you can always use the sand hour glass as a timer to time your friends while playing chess, scrabble, boggle, or other games.

ARVIND GUPTA

Mr. Gupta is with the People's Science Movement, Maharashtra.

Rules of thumb

THERE'S THIS story of a village mother-in-law who had three daughters-in-law. And like most folk lore mothers-in-law, this one also took life easy, assigning chores to the younger women. And the chores were distributed among the three quite fairly. Only in dire circumstances did the mother-in-law share their burden.

The task of cooking was assigned to the petite dainty daughter-in-law. One day, while the lady in charge of the kitchen was away visiting her parents, a hoard of guests dropped in and it fell to the youngest daughter-in-law to cook for them. On instructions from the lady of the house, she added two handfuls of salt to the curry. It became uneatable — just too salty. Thinking that she had done it out of spite, the old lady assigned the job to the other daughter-in-law the next day. The result was even worse. Meanwhile, the petite one returned and conditions improved.

After the guests had left, the mother-in-law admonished the two awful cooks. But they pleaded "We only followed your instructions". They had. So what exactly went wrong. The answer's simple: the amount of salt in the "handful" of the three young women varied greatly. Maybe the story's an exaggeration, but don't folklores thrive on that?

If you visit villages even today measurements are done by approximate means. A villager many check the length of a piece of cloth by stretching it from the tip of her nose to the end of her extended hand or from the tip of her finger till her elbow. Small lengths, might be told as number of finger breadths; weights may be told in the form of "as much as that vessel filled with water", a house, field or a depth of a pond etc may be described as "so many man lengths, or bullock lengths".

Measures have been used loosely and where there has been no need for high accuracy they have served a purpose. Why, a friend in Bombay who had bought a new flat described it to be thus "Twenty persons can sit comfortably in the living room so you can judge its area"; I was foxed but my other friend, also from Bombay, seemed to understand it perfectly.

When one uses such subjective forms of measurements there is always the danger of errors. So one has to be a little more specific. That's where standardized measures come in. One square cm is the same no matter who marks it.

But one can't always carry around a measuring device. some people do. There are some easy ways of measuring using everyday objects. The secret here, however, is that these objects are standardized against known meausres. There are several thumb rules for this.

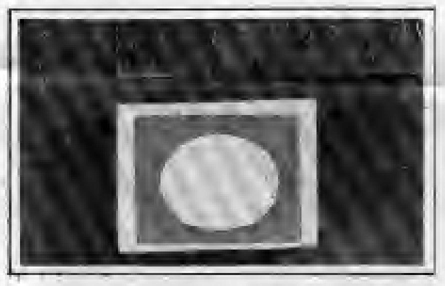
Thumb rules are ready reckoners which enable you to compare and crosscheck your estimates with ease. One such ready reckoner is the matchbox, a low-cost universally available item of everyday useage. Millions of matchboxes are manufactured per day in factories. Because the matchbox is mass produced and factory made, its size and dimensions conform to certain standards. The same is true of many other objects in daily use. Let's discover some fascinating facets of this most familiar cuboid-the matchbox.

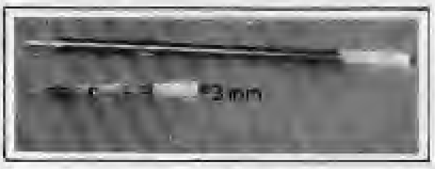
The length of a matchbox is always 5 cm (2 inches) and so it can be used for estimating length. The length of six matchboxes kept end-to-end equals 30 cm or almost one foot. Some other objects can also be used as good estimates for measurement of length. The postcard, for instance, is always 14 cm long and 9 cm broad. A ballpen plastic refill tube has an outer diameter of 3 mm. Matchsticks have a square cross-section. Each side of this square measures 2 mm. Normal bicycle spokes are 30 cm (or one foot) long. Normal bricks are 9 inch long (22.05 cm) Coins have standard dimensions. They can be used as fairly accurate measures to estimate length.

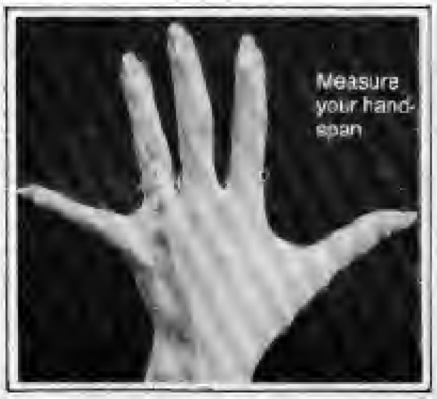
Thus even if you don't have a ruler at hand, you can always use some matchboxes, coins etc to estimate length

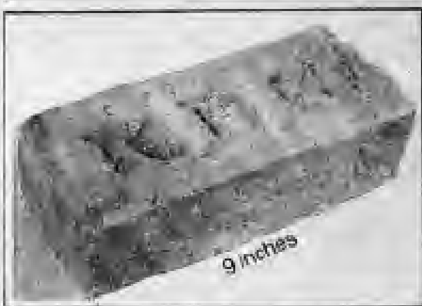
Try to guess lengths by looking at the object. Before measuring, first make a mental estimate of the length of the object. Then measure it either with a scale or with some improvised thing whose length you already know. Compare the difference between your guess and the actual measured length. This way you can refine your estimations; you can even use your hand. You could, measure the length of your handspan and use it for approximating different lengths. And now, one for the road. How much distance do you cover in one step while walking? You can use this estimate for approximating long distances like how far is it from the bus stop to your house.

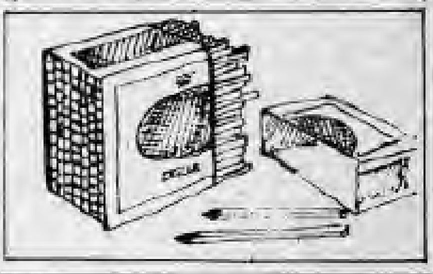
A matchbox has three distinct surfaces — the label surface (A), the strike surface (B) and the drawer surface (C). Why is











(A) bigger than (B), when both of them share a common length? Why is (B) bigger than (C), when both of them share a common breadth? Area depends on both length and breadth, and a change in either of these dimensions will lead to a change in area.

How can you find the area of the matchbox shell in which the drawer fits? One simple way, of course, is to measure the length and breadth and then to multiply them. There is, however, a very interesting way of finding the area of the matchbox shell. You've just seen that the cross-section of matchsticks is 2 mm × 2 mm Matchsticks can be used as standard "bricks", for measuring area. Pack burnt matchstick "bricks" in the outer shell of a matchbox, to construct a wall. The area of each "brick" is a standard and is already known. By counting the total number of matchstick "bricks" used, you can estimate the area of the matchbox shell. A large area is composed of many small areas. Obvious, isn't it?

But why is it useful to know that? Well, if you know the area of a unit component, you could calculate the area of the whole. For example, by counting the tiles in a room you could tell its area. And in case of an irregular shape, you could divide up the space into easily measurable dimensions and add up the areas of several bits to get the area of the whole.

The two dimensional graph is an abstraction. But the square matchsticks snugged together in the matchbox shell can give a concrete feel of the graph paper.

Dip a little cotton ball in oil and rub it on the matchbox drawer. Soon the wood and the paper of the matchbox drawer will absorb the oil. Dry the drawer in the sun. By oiling, the drawer becomes waterproof. This drawer when filled with water holds approximately 20 millilitres (ml) of water. (The drawers' capacity is a good estimate for measuring 20 ml.) You can use this as a rough standard for measuring volume. To make a volume measuring device stick a thin strip of white paper along the length of a bottle. (It would be nice if you could get a tall thin bottle of more or less uniform diameter.) Now, fill up a matchbox drawer level full with water and pour it in the bottle. Indicate the water level in the bottle by marking a line on the paper. This line becomes the 20 ml mark. Add more drawers full of water in the bottle, each time marking the levels: 40 ml, 60 ml, 80 ml, 100 ml etc on the paper strip. You can put mid points between these graduations to indicate 10 ml difference marks. This graduated bottle becomes a measuring cylinder for liquids. If you fill the bottle up to the 100 ml mark, and then pour it out in a bucket and repeat it ten times, you can have a measure for 1,000 ml or one litre. (A milk bottle generally holds 500 ml (½ litre) of liquid.

Make a simple balance using leaf cups or boot polish tins for the pans. The pans can be suspended with strings and then hung on either side of a uniform stick. Ensure that the balance point is equidistant from the two pans. Only then will the balance weigh truly. If the beam isn't properly balanced, gently pour sand in the raised pan until the beam becomes horizontal. Now, keep a matchbox drawer on each of the pans. As the drawers have the same weight the beam will remain balanced. Fill the left hand drawer with water up to the brim. You already know that the drawer holds 20 ml of water. And 1 ml of water weights 1 g — the density of water. So, 20 ml of water will weigh 20g. It amounts to putting a 20g weight in the left hand pan. Place an appropriate length of any junk wire in the right hand pan to balance the beam. This wire shall now weigh 20g. Straighten out the wire and cut it into half and quarter lengths to make 10g and 5g weights. You can similarly make 50g and other weights.

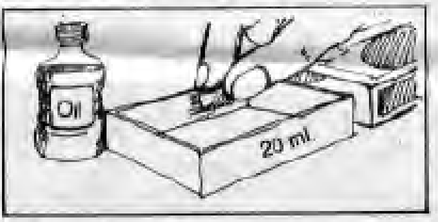
We all carry standard weights in the form of coins in our pocket. You must often have seen shopkeepers using coins to weigh small quantities of material. The approximate weights of some of the coins are:

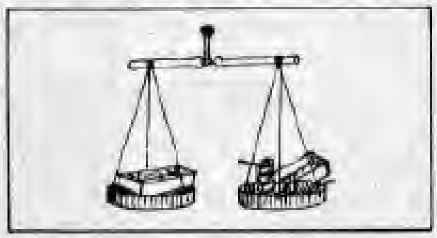
One rupee coin (old)	8 g
One rupee coin (new)	6 g
50 paise coin	5 g
25 paise coin	2.5 g
5 paise coin (aluminium)	1.5 g

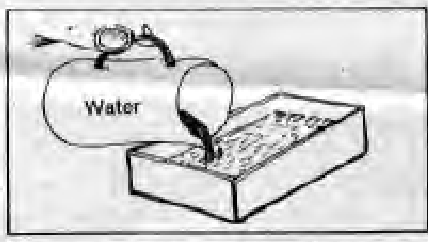
Thus two, twenty-five paise coins equals a fifty paise coin not only in monetary value, but also in weight. This is a very interesting relationship.

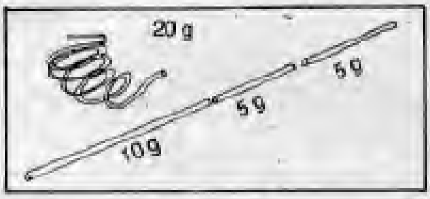
A sealed, brand new matchbox is a good estimate for 10 g; 50 unburnt matchsticks weigh approximately 5 g. Thus, 10 matchsticks are a good estimate for 1 g, and one single unburnt matchstick a very good estimate for 0.1 g.

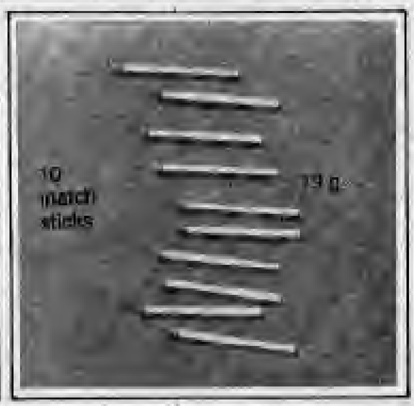
After having learnt to make measuring devices and measure, you are probably on the right way of thinking quantitatively. And to think of it we still have measures like Manday — the work a man can do in one day.









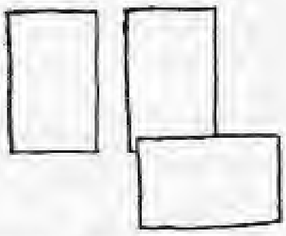


ARVIND GUPTA

Mr Gupta, an electrical engineer, has been involved with People's Science Movements. At present he is on a DST fellowship writing a book on matchstick meccano and other science experiments.

Perfect match(es)

NATURE IS replete with symmetry. The human body, the wings of a butterfly, the markings on a beetle's back, the vein patterns on leaves, etc are symmetrical in nature. In each case one half can be folded over the other to match exactly. The fold represents the line of symmetry. For instance, when a butterfly folds its wings they match exactly, the axis of symmetry being the length of the butterfly's body. That is bilateral symmetry.



Cut an old post card into half along its length. Put it on a large piece of paper and push a pin or a thorn through one corner. Put it straight on the paper and draw a line around it. Now, turn it a quarter and draw around it again (Fig 1). Give it another quarter turn, and another — drawing around it each time (Fig 2).

Next, cut a triangle in the rectangle and outline the cut-out, but this time you'll have to draw inside the triangular hole instead of around the whole paper. Repeat the process by rotating the card. Then cut some other shape, say a circle, and rotate the paper and draw to make a new pattern (Fig 3).

Fold a piece of paper in half. Cut shapes around its edges. Then open it to see the pattern you have made (Fig 4).

You can use leaves too for this purpose and invent lots of new shapes (Fig 5).

If you have a mirror, even a broken one with one straight edge, draw a shape and put the mirror beside it so that the shape doubles itself in the mirror (Fig 6).

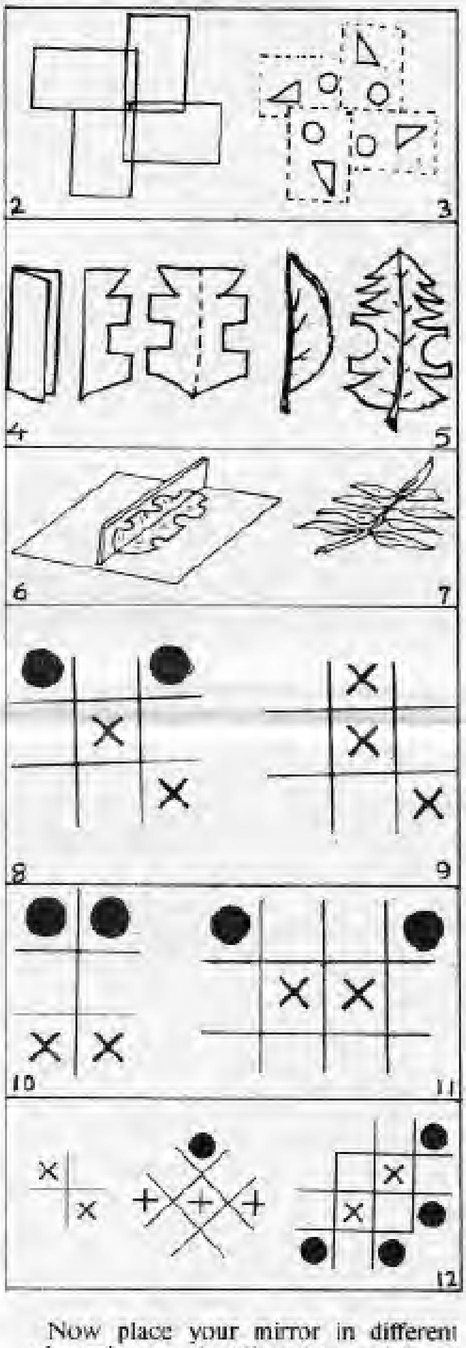
Some leaves, especially compound leaves, look as if they have been doubled in a mirror. (Fig 7).

Place the straight edge of the mirror on Fig 8. Slide and turn the mirror to see the patterns change. Now orient the mirror on Fig 8 in such a way so that you can see the patterns that match with Fig 9. Notice that you have made the circles disappear and that you can now see four crosses.

Again place the mirror on Fig 8 so that you can see a pattern that matches with Fig 10. Is your mirror on a vertical line facing to the right?

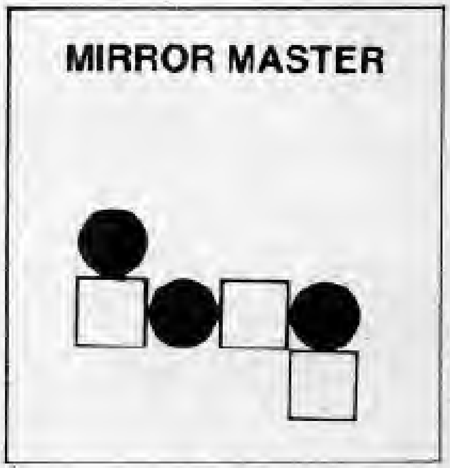
Once again, place the mirror on Fig 8 to get Fig 11. Notice that you had to face the mirror to the left.

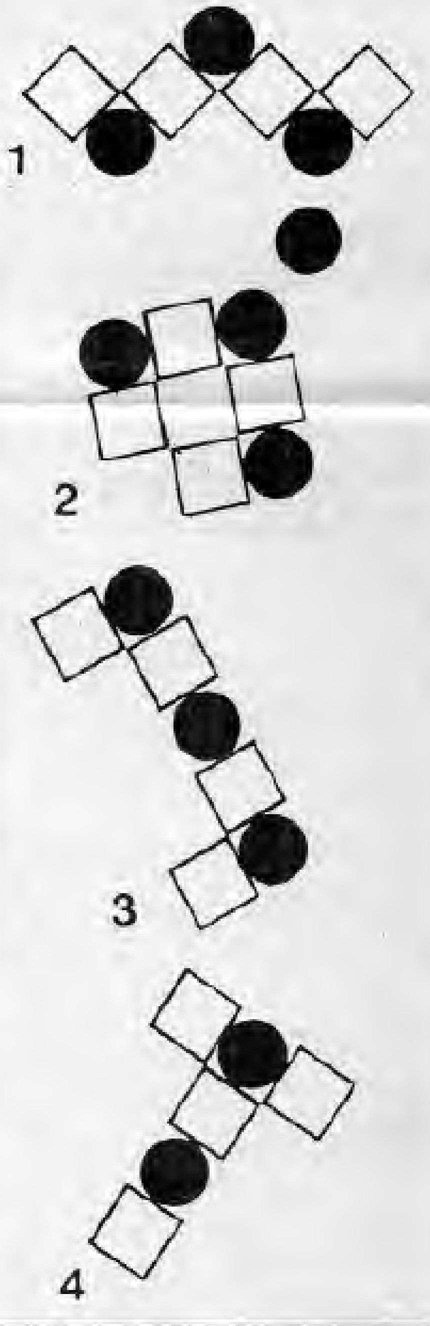
Once again, place the mirror on Fig 8 to get all the different patterns shown in Fig 12.

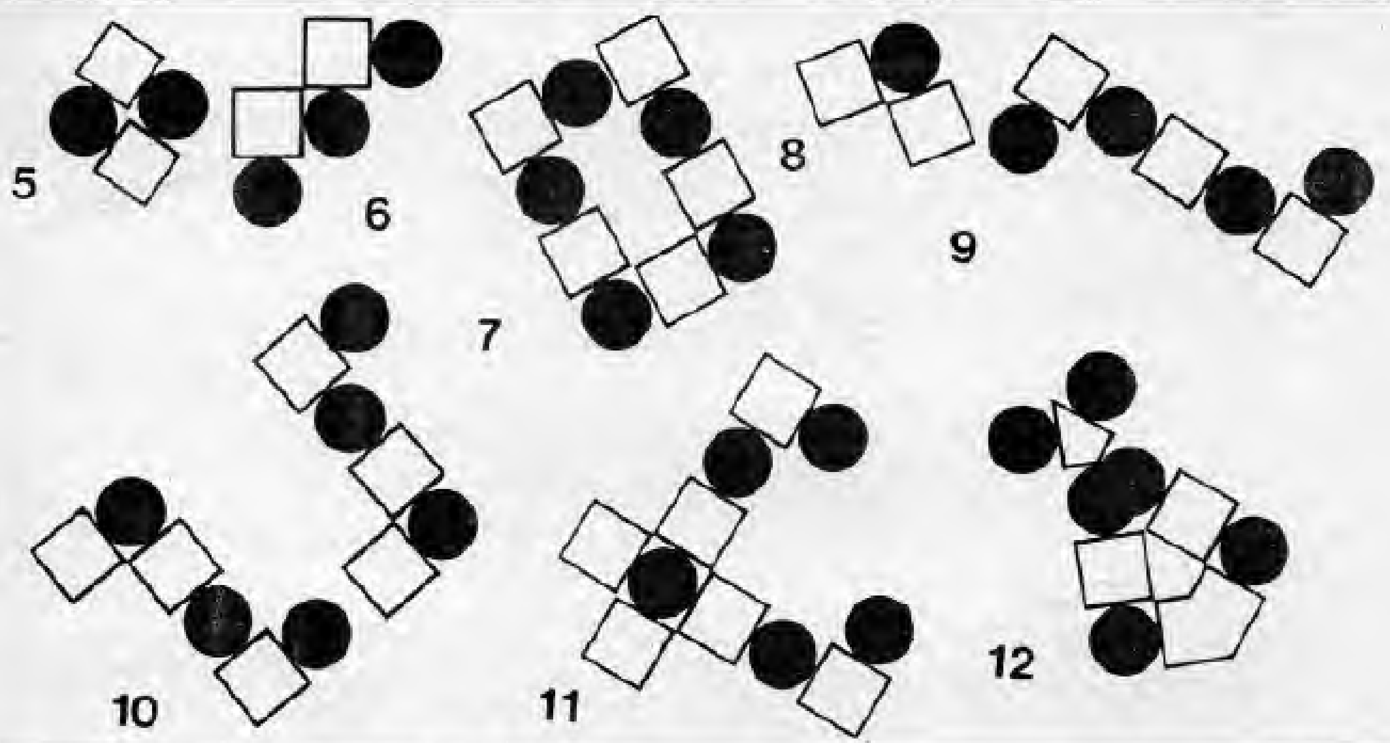


Now place your mirror in different orientations on the Mirror Master (Fig 13) and try and get all the patterns, or atleast as many as you can. You'll be able to get most of them. But some of the patterns have been given to trick you, they are not merely difficult to get; they are impossible. Can you locate the impossibles?

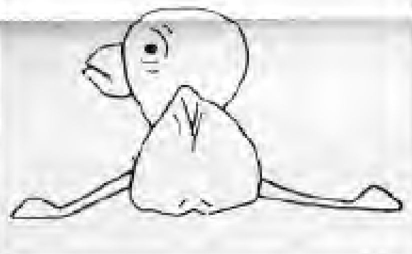
Do the same with the mirror master in Fig 14. And if you have enjoyed these mirror puzzles, why not make some of your own?

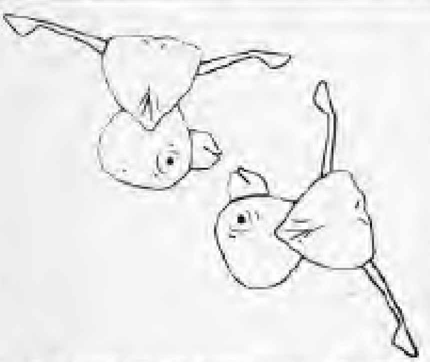


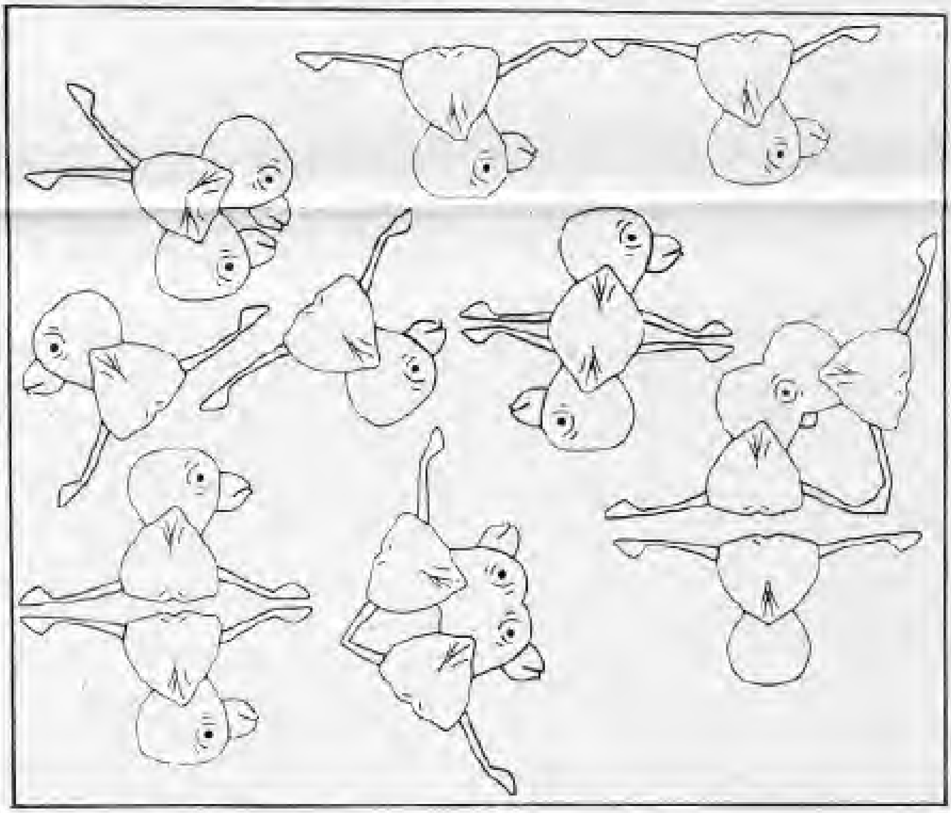




MIRROR MASTER







Try looking for symmetries. You'll find them everywhere — even in the alphabets and numerals. Which alphabets have no lines of symmetry? Which have one? Two? Find the alphabets in SCIENCE AGE which have at least one line of symmetry. When you have done this and would like to learn more tricks you can refer to these two books: *Preparation for Understanding* by Keith Warren and *The Mirror Puzzle Book* by Marion Walter.

You must have seen that some shapes have more than one lines of symmetry. Some have none. A square has four lines of symmetry. Place the mirror on each of the four lines and see how the square remains unchanged. Can you place the mirror to make squares of different sizes?

On the other hand, any line which passes through the centre of a circle is a line of symmetry, but can you place the mirror to make different sized circles?

ARVIND GUPTA

Mr Gupta is an IIT-Kanpur trained engineer. He has been associated with several educational and development groups and has written and translated many popular science books and articles.

A pump from the dump

SOMETHINGS ARE better learnt by doing — by making a simple model and seeing it actually work. Take, for example, the simple hand pump the principle of which we learn at school. How a simple handpump operates is still an enigma to many. For the average villager, the handpump is an important machine for quenching thirst. With no piped water in most villages, the handpump still remains the mainstay of potable water for the majority of our people.

Here is a simple way of making a sturdy handpump. All you need will be a few odds and assemble them together into this working model of the handpump. This will be a good way to test out the validity of the principles of the handpump in actual practice. With each reciprocation of the piston, water will leap out in large gushes and delight you no end.

Some odds-and-bits

As with most hand pumps this one too consists of a cylinder and piston assembly and two valves — one for the suction and the other for the delivery. But before you jump at the pump you'll have to collect a few odds-and-bits which will go into making its different parts. You'll need a bottle, an old milk bag, a cycle wheel spoke, a ball pen, a bottle cap, cycle puncture solution, an old chappal, scissors, a knife and a needle.

The cylinder

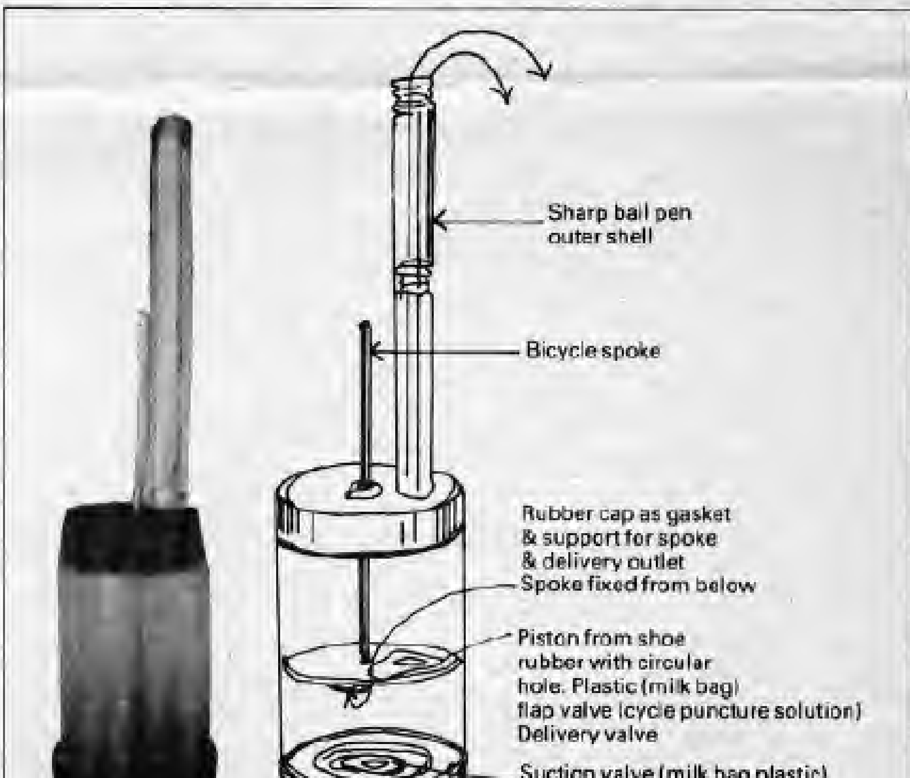
In theory, any pipe-like object with a circular and uniform cross-section could serve the purpose of a cylinder. For instance, a broken test-tube could serve adequately. It has the advantage of being clearly transparent, so that you can have a good look at the opening and closing of the valves. But a test-tube is likely to break and since its sharp edges can gash your skin, it has to be discarded. Your best bet would be a cylindrical plastic bottle (preferably transparent) with a cap — which either screws on, or snaps into, the top. You can easily find an empty medicine bottle to make a suitable cylinder. The bottle should have a bore between 2 to 4 cm and a height between 4 to 8 cm. Of course, the greater the bore and the height, the larger will be the capacity of the cylinder. Consequently, it will pump out a larger amount of water with each stroke.

I myself used a transparent plastic bottle which houses 35 mm colour film roll for the cylinder. Its great advantage is its semi-transparency, which enables one to have a peek at the valves in operation. In the pump this bottle will be used in the upside-down position, with the black, snap-on cap at the bottom.

The piston

The piston is made out of 3 to 5 mm thick rubber sole of a shoe or chappal. A uniform section of a used rubber chappal would be quite suitable. First, mark a circle on the rubber sheet equal in size to the internal diameter of the bottle. Then cut out the circular piston either with a pair of scissors or a sharp knife. The rim of the circular rubber piston is sandpapered until it fits snugly into the cylinder.

Make a hole in the centre of this piston with a divider point. A 15 cm long cycle wheel spoke is inserted through this hole, the head of the cycle spoke sits at the bottom of the piston and prevents the rubber piston from slipping out. The cycle spoke becomes the rod of the pump and enables one to reciprocate the piston.



The delivery-valve

A 8 mm hole is made between the cycle spoke and the rim or the circular piston. This hole need not be circular in shape. A plastic bag flap (made from a used milk bag) is stuck with a water insoluble adhesive (cycle puncture (rubber) solution or Fevibond) on one side of this hole. The flap adheres to one side but is free to open and close the hole. This delivery valve is located on top of the piston.

The suction-valve

A 8 mm hole is made in the centre of the black cap, either by using a shoemaker's punch, or else by chain drilling making a series of holes on the 8-mm circle with a hot pin and removing the central plastic core. A milk bag flap is stuck to one side of this hole using a rubber solution, on the inside surface of the black cap. The plastic bag strip acts as "flap valve", opening and closing the hole thus enabling water flow in one direction only.

The pump-base

The suction-valve cannot be kept in direct contact with the base of the water reservoir, for the simple reason that the reservoir base will cover the suction hole and choke any suction that occurs. The black cap therefore needs to be raised above the water base. I propped the pump

Inlet hole of the piston barrel showing plastic valve

The piston showing plastic valve

on a Camlin poster colour bottle cap, and provided three holes on its side for free suction. This cap also provides a sturdy base for the pump.

Assembly

A small hole is made in the centre of the plastic bottle to enable the spoke to pass through. Another 5-mm hole is made on the base of the bottle near the edge for the

Pumping up the liquid

water outlet. A 8-mm thick rubber sale of a shoe is cut to fit the circular base of the plastic bottle. A hole is made in this rubber gasket to enable the spoke to come out. Another hole is made corresponding to the water outlet. This rubber is now stuck with cycle puncture solution on the external surface of the bottle base. This rubber acts as a support for the cycle spoke and also prevents leakage. A broken ball-pen outer case can now be inserted in the rubber hole corresponding to the water outlet. This will be the delivery pipe.

Now insert the cycle spoke piston delivery valve assembly into the cylinder. The cycle spoke will come out of the rubber top. Snap on the bottle cover. Both suction and delivery valves will open upwards. Screw on the delivery pipe. Place the pump on its base, and lower the whole assembly in a reservoir of water.

The liquid enters through the holes in the base, is raised by the piston and overflows through the tube made of the ball-pen body

Operation

Within a couple of up-and-down strokes of the piston, water will gush out with great force from the delivery pipe. To understand its operation let us consider the piston at its bottom-most position. As the piston is pulled up 1a partial vacuum is created in the chamber, because of which the suction-valve opens and sucks up water from the reservoir. All this while the delivery-valve (on top of the piston) remains closed. This continues throughout the upward stroke of the piston.

On the downward stroke of the piston the suction valve is closed shut. The delivery-valve on the piston opens and allows the water to get stored above the piston.

On the next upward stroke, the water trapped above the piston gushes out through the delivery pipe, as the delivery-valve remains closed. Simultaneously, the suction valve opens and allows water to be sucked up from the reservoir. The valves open and close like a fish's gills and can be observed clearly through the transparent bottle. They give a very good feel of how valves operate.

In this model you have got to reciprocate the cycle spoke to pump out water. Can you attach a fork and a handle to make it look like an actual handpump?

ARVIND GUPTA

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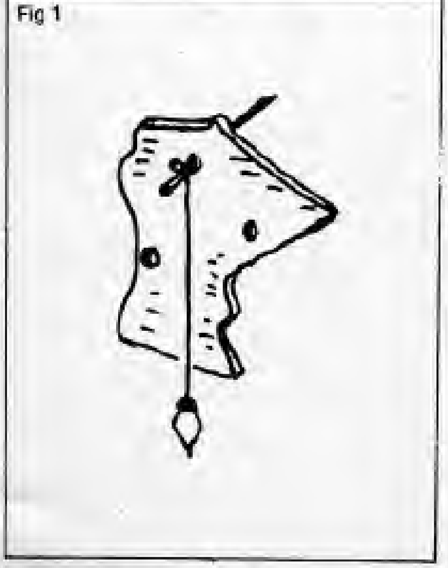
Mass at a point

WHAT DECIDES the height of a railing of a terrace or balcony? The railing should be slightly higher than the navel level of an average adult. This is because the navel represents the approximate centre of mass of the human body. So, if by chance, an adult leans over the railing, he is unlikely to tip over and fall down. Children are unlikely to fall, unless they are up to some pranks, because the railing height would be far above their navel level.

But what is the centre of mass? Though a man has his weight distributed over his hands, legs, head and various other organs, nevertheless, it can be shown that in some ways all real bodies behave as if their mass were concentrated at a single point. This point is the centre of mass. When a body is symmetrical in shape, and when it is either uniform in density or has a density that changes in a symmetrical fashion, the centre of mass is at the geometrical centre of the body. For instance, the Earth is essentially a spherical body; while it is not uniformly dense, it is most dense at the centre, and this density falls off equally in all directions as one approaches the surface. The Earth's centre of mass therefore coincides with its geometric centre, and it is towards that centre that the force of gravity is directed.

Now suppose that a body is falling towards the Earth. Every particle of the body is being pulled by the force of gravity, but the body behaves as if all that force is concentrated at one point within the body; that point is the centre of gravity. In a uniform gravitational field, the centre of gravity would be identical with the centre of mass. However, the lower portion of the body is usally closer to the centre of the Earth than the upper, so the lower portion is more strongly under the gravitational influence. The centre of gravity is consequently slightly below the centre of mass.

Fig 1

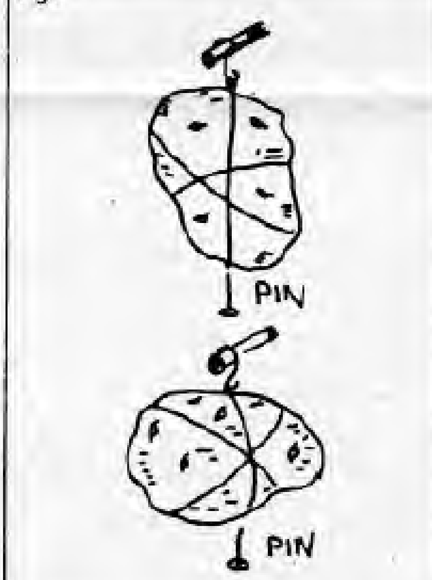


The centre of mass of a regular shaped body can be found by marking its geometric centre. For instance, you can find the centre of mass of a steel thali or a book by trying to balance it on the tip of your finger. You can find the centre of mass of an irregular shaped body by hanging it with a plumb bob from various points. In each case the centre of gravity of the object will orient itself with the minimum potential energy on a vertical line below the support point (Fig 1). The intersecting point of these vertical lines will give the centre of mass.

Centre of gravity of a potato

Tie a string around a potato so that it can be hung in several positions. After suspending the potato, stick a pin into it at the bottom along the support line. Hang the potato in several different positions and stick a pin in each position. All the pins will point to the centre of gravity (Fig 2).

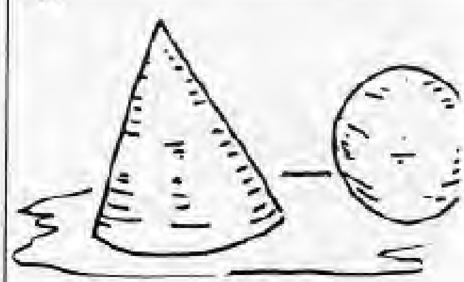
Fig 2



Stability

The concept of the centre of gravity is useful in considering the stability of bodies. Imagine a brick resting on its narrowest base. If it is tipped slightly and then released, it drops back to its original position. If it is tipped somewhat more and then released, it drops back again. As it is tipped more and more, there comes a point when it tips over. How does one explain the tipping? As long as the centre of gravity is located directly over some portion of the original base, the effect of the gravitational pull is to move the brick back upon that base once the tipping force is removed. If the brick is tipped so much that centre of gravity is located outside the original base, then the brick tips over. Naturally, the wider the base in comparison with the height of the centre of gravity, the more stable the body. A brick resting on its broadest base is more stable than one resting on its narrowest base.

Fig 3

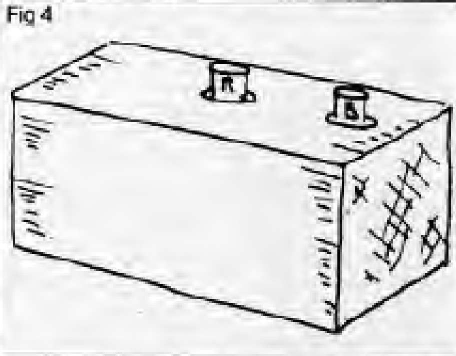


Thus, a cone can be stable on its base, have neutral stability on its side, and be unstable on its point (Fig 3). A sphere has neutral stability in all positions.

Motion of the centre of mass

Take a wooden block and drill two holes in it so that two sketch pens can be inserted. One hole passes through the centre of mass of the block and the other is to one side. Place the block on a large sheet of paper and give it a sharp off-centre blow with a hammer. The pen trace connected with the centre of mass will be a straight line, while the other trace will move about this line (Fig 4).

Fig 4

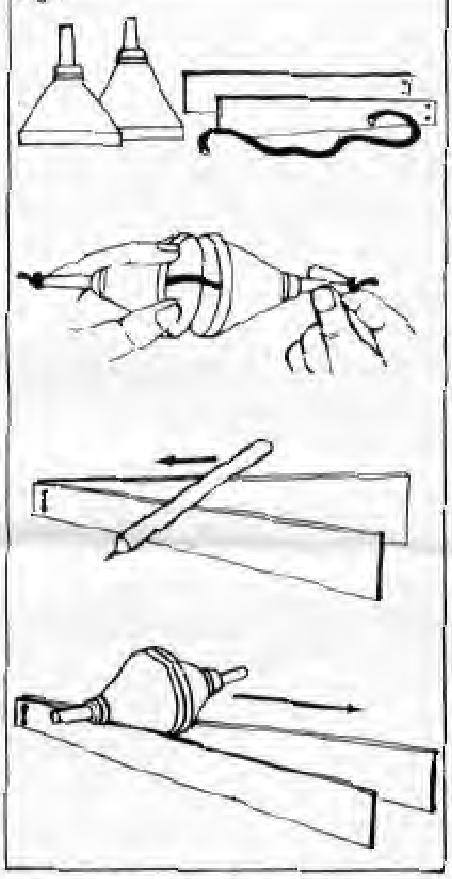


Rolling uphill

For this you will require a double cone — two cones back-to-back — and a V-shaped rail system such that the open end of the V is higher than the closed end. Take two similar sized plastic funnels and place their broad ends together. Weave a

rubber band or a cycle valve tube through the funnels. Stretch the rubber band and tie a knot at both the ends. The taut rubber band will keep the funnels back-to-back, making a double cone assembly. For making the rail take two pieces of cardboard approximately 25 cm long. Their width should taper from 7 cm at the higher end to 5 cm at the lower end. Their lower ends are joined and a matchbox is wedged between them to give a V-shaped ramp (Fig 5)

Fig 5



Any cylindrical object, say a pencil, placed on the higher end of this incline rolls downhill as should be expected. However, when you place the double cone on the lower end of the ramp it tends to climb uphill — an apparent paradox. This peculiar behaviour can however be logically explained. A double cone is cut at an angle so that as the cone rolls on the rails its centre of mass is lowered. The double cone will roll uphill if the centre of mass is lowered faster than the rail system can raise it.

ARVIND GUPTA

Mr Gupta, an IIT-Kanpur trained engineer, has developed chapters on machines and structures for experiment-based science teaching in rural schools. He has been associated with several educational and development groups and has translated/written many popular science books and articles in Hindi.

SCIENCE ON STAMPS

Balloon flights

THE HUMAN mind has always associated flying with freedom and power. The mythologies of many ancient civilizations include gods and other mythical beings with the wings of birds. History is replete with examples of men trying to soar into the skies, but the first one to seriously consider the problem is perhaps that great Renaissance figure, Leonardo da Vinci, whose notebooks reveal detailed sketches of flying machines similar to today's helicopters.

The first attempts to actually fly were made with hot air balloons. In 1783, the Montgolfier brothers, Jacques and Etienne, launched the first unmanned balloon flight in history. The first manned flight took place soon after, on 21 November of that year. Two hundred years later, in 1983, several countries, including Brazil, Poland, USA, India and Cuba, commemorated this event by issuing a number of colourful stamps depicting their own attempts at flying in the sky.

Among the block of four stamps of USA, the vertical stamp at the left depicts the hot air balloon, *Intrepid*. It was used for aerial surveillance by the Union army during the American civil war (1861). Thaddeus Lowe manned the balloon, giving progress reports to President Abraham Lincoln at 15-minute intervals. The two horizontal designs depict 13 multicoloured modern-day hot air balloons in flight. And the vertical stamp to the right depicts Explorer-II, a balloon used jointly by the National Geographic Society and the US Army for scientific research.

The Brazilian stamp shows an ascending balloon enveloped in a dream-like atmosphere, with a blue sky, white clouds and a rainbow, going into a second plane in black and white. This superimposition of planes accentuates not just the balloon's great beauty, but also its importance as a pioneer in the conquest of space.

Interest in ballooning as a sport increased greatly when James Gordon Bennett (1841-1918) offered a trophy and a substantial sum of money as a prize to the winner of an annual long-distance race.

Poland released six colourful stamps in one block in order to popularize the sport, with special attention being paid to the country's success in competitions for Gordon Bennett's Cup.

Ballooning in India began as early as in 1877. However, the Ballooning Club of India was founded only in 1979. The country, too, commemorated the first balloon flight by issuing two special postage stamps. The 100p stamp features the first Indian-built hot air balloon, Udan Khatola, flying over the Taj Mahal. The other stamp (200p) depicts the first Montgolfier balloon.

KABITA ROY

Ms Roy is an amateur philatelist from Calcutta.

LITTLE SCIENCE

Learning from soap bubbles

Soap Bubbles and the Forces Which Mould Them is a classic of science literature. Its author, C V Boys, was one of the most colourful British scientists. Though trained in mining and metallurgy, he invented an integrating machine and radiomicrometer, did a monograph on spiders, and devised a precision equipment for determining the value of the Newtonian constant of gravitation. In his old age he developed an ardent interest in gardening, and, since he was the kind of man he was, this led inevitably to his writing his final book *Weeds, Weeds, Weeds* (1937). When he died on 30 March 1944, he held a high place in science, indeed, but it may be safe to predict that he will be remembered longest and best for the pleasure which thousands of readers have found and will find in his little gem of a book on soap bubbles. The book is a collation of three lectures that he delivered before a juvenile audience at the London Institution on 30 December, 1889, and on 1 and 3 January 1890.

It is possible that some of you may like to know why I have chosen soap bubbles as my subject. Though there are many subjects which might seem to the beginner to be more wonderful, more brilliant, or more exciting, there are few which so directly bear upon the things which we see everyday. You cannot pour water from a jug or tea from a tea-pot; you cannot do anything with a liquid of any kind, without setting in action the forces to which I am about to direct your attention. Many of the things discussed here are so simple that you will be able without any apparatus to repeat for yourselves the experiments described.

When we want to find out anything that we do not know, there are two ways of doing it. We may either ask somebody else who knows, and read what the most learned men have written about it, which is a very good plan if anybody happens to be able to answer our question; or else we may adopt the other plan — by arranging an experiment, try for ourselves. An experiment is a question which we ask of Nature, which is always ready to give a correct answer, provided we ask properly, that is, provided we arrange a proper experiment. An experiment is not a conjuring trick; its chief object is to enable you to see for yourself what the true answers are to the questions asked.

Now let's perform an experiment which you have all probably tried dozens of times. Take a paint brush. If you want to make the hairs cling together and come to a point, you wet it, and then you say the hairs cling together because the brush is wet. When it is dry the hairs are separately visible. After dipping it in water and on taking it out, the hairs, as we expected, cling together. Is it because "they are wet", as we are in the habit of saying. I shall now hold the brush in the water, but there the hairs do not cling at all and yet they surely are wet now (Fig1).

It would appear then, the reason which we always give is not exactly correct. This experiment which requires nothing more than a brush and a glass of water shows us that the hairs of a brush cling together not only because they are wet, but for some other reason as well which we do not yet know. This experiment, though it has not exactly explained why the hairs cling together, has at any rate told us that the reason always given is not sufficient.

Try another experiment as simple as the last. I have a pipe from which water is dropping very slowly, but it does not fall away continuously; a drop forms which grows slowly until it has attained a certain definite size, and then it suddenly falls away. Notice that every time this happens the drop is always exactly the same size and shape. Now this cannot be mere chance; there must be some reason for the definite size, and shape.

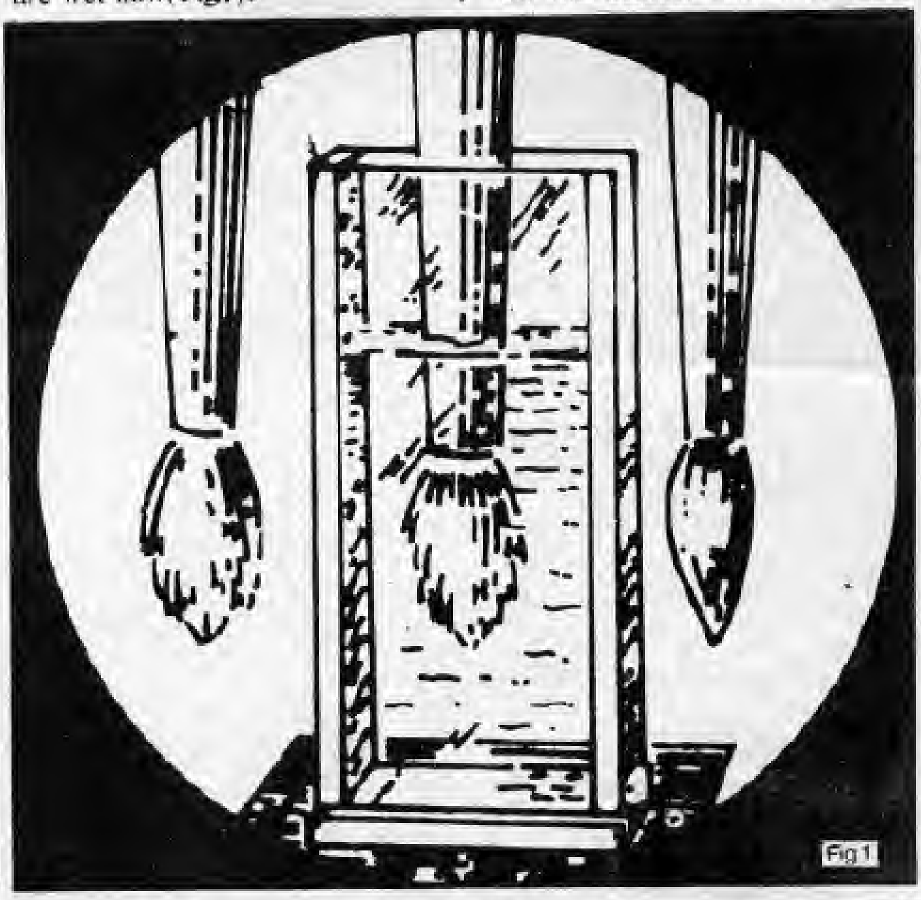


Fig 1

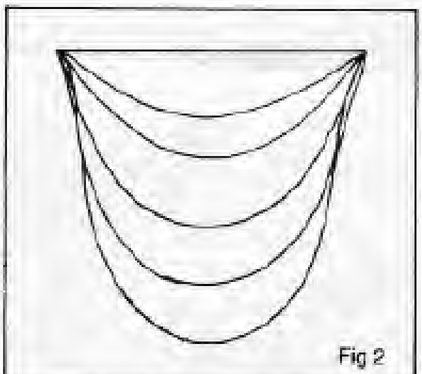


Fig 2

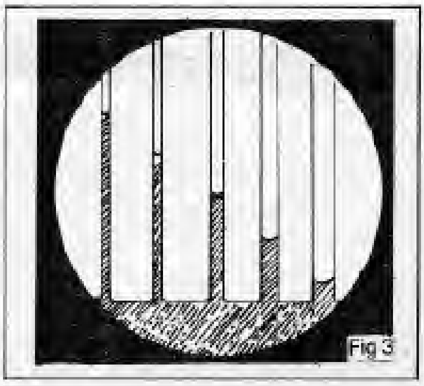


Fig 3

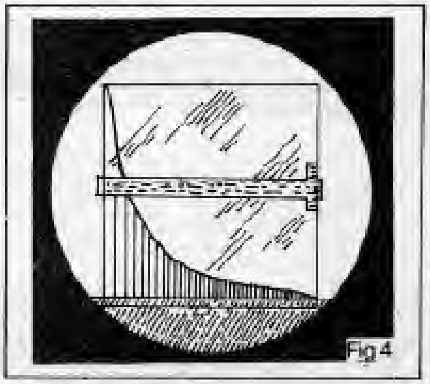


Fig 4

Why does the water remain at all? It is heavy and ready to fall, but it does not fall; it remains clinging until it is a certain size, and then it suddenly breaks away, as if whatever held it was not strong enough to carry a greater weight. Fig 2 will probably suggest the idea that the water is hanging suspended in an elastic bag, and that the bag breaks (or is torn away) when there is too great a weight for it to carry. It is true that there is no bag at all really, yet, the drops take a shape which suggests an elastic bag.

Let us see how this fits the first experiment with the brush. That showed that the hairs do not cling together simply because they are wet; it is necessary also that the brush should be taken out of the water, or in other words it is necessary that the surface or the skin of the water should be present to bind the hairs together. If then we suppose that the surface of the water is like an elastic skin, then both the experiments with the wet brush and with the water drop will be explained.

Now dip into the water a very narrow glass pipe, and immediately the water rushes up and stands half an inch above the general level. The tube inside is wet. The elastic skin of the water is therefore attached to the tube, and goes on pulling up the water until the weight of the water raised above the general level is equal to the force exerted by the skin. If I take a tube twice as big, then this pulling action which is going on all round the tube will cause it to lift twice the weight of water, but this will not make the water rise twice as high, because the larger tube holds so much more water for a given length than the smaller tube. It will not even pull it up as high as it did in the case of the smaller tube, because if it were pulled up as high, the weight of the water raised would in this case be four times as great, and not only twice as great, as you might at first think. It will therefore only raise the water in the larger tube to half the height, and now that the two tubes are side by side you see the water in the smaller tube standing twice as high as it does in the larger tube. In the same way, if I were to take a tube as fine as a hair the water will go up ever so much higher. It is for this reason that this is called capillarity (comes from the Latin word capillus, a hair) because the action is so marked in a tube the size of a hair.

Supposing now you had a great number of tubes of all sizes (Fig 3) and placed them in a row with the smallest on one side and all the others in the order of their sizes, then it is evident that the water would rise highest in the smallest tube and less and less high in each tube in the row until when you came to a very large tube you would not be able to see that the water was raised at all. You can very easily obtain the same kind of effect by simply taking two square pieces of window glass and placing them face to face with a common match or small fragment of anything to keep them apart along one edge while they meet together along the opposite edge. A rubber band will hold them in this position. Take this pair of plates and stand them in a dish of coloured water, and you will at once see that the water creeps up to the top of the plates on the edge where they meet, and as the distance between the plates gradually increases, so the height to which the water rises gets less, and the result is that the surface of the liquid forms a beautiful regular curve which is called by mathematicians a rectangular hyperbola (Fig 4). The hyperbola is formed because the width between the plates gets greater, the height gets less, or, what comes to the same thing, because the weight of liquid pulled up at any small part of the curve is always the same.

And a soap bubble remains a bubble because of these very forces.

ARVIND GUPTA

Mr Gupta, an IIT-trained engineer, has been associated with many educational groups. He has written several popular science books and articles, especially for children.

TEASER

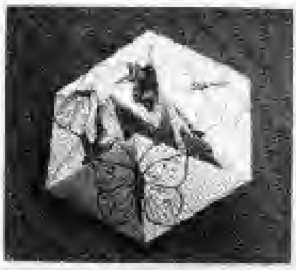
AN INSECT which can crawl but cannot fly is in one corner of the floor of a room $15' \times 10' \times 10'$. It crawls to the diagonally opposite corner of the room on the ceiling by the shortest possible path. What is the distance it travels?

DIPAN GHOSH

Solution to last month's teaser

Let there be x cowherdesses and y cows so that $x + y$ is a perfect quare and $x + y + y = 13$ (heads and tails). Also there were $2x + 4y$ legs in all; that is, $2(x + 2y) = 2 \times 13 = 26$ legs. Now $x + y$ should be 4 or 9. With $x + y = 4$, $x + 2y$ cannot be 13. So $x + y = 9$ and $x + 2y = 13$. Solving, the equation we get $x = 5$ and $y = 4$.

Hexagonal rotating ring



EVERY SCHOOL worth its name boasts of physics, chemistry and biology labs. But seldom does one hear of a maths lab where children can make and play with mathematical models, solve puzzles and generally enjoy themselves. This is essential. Any person would need a variety of concrete experiences before he can begin to grasp abstractions. When the dreary school maths curriculum loads and goads young minds with abstruse mathematical abstractions, it creates a distaste for mathematics.

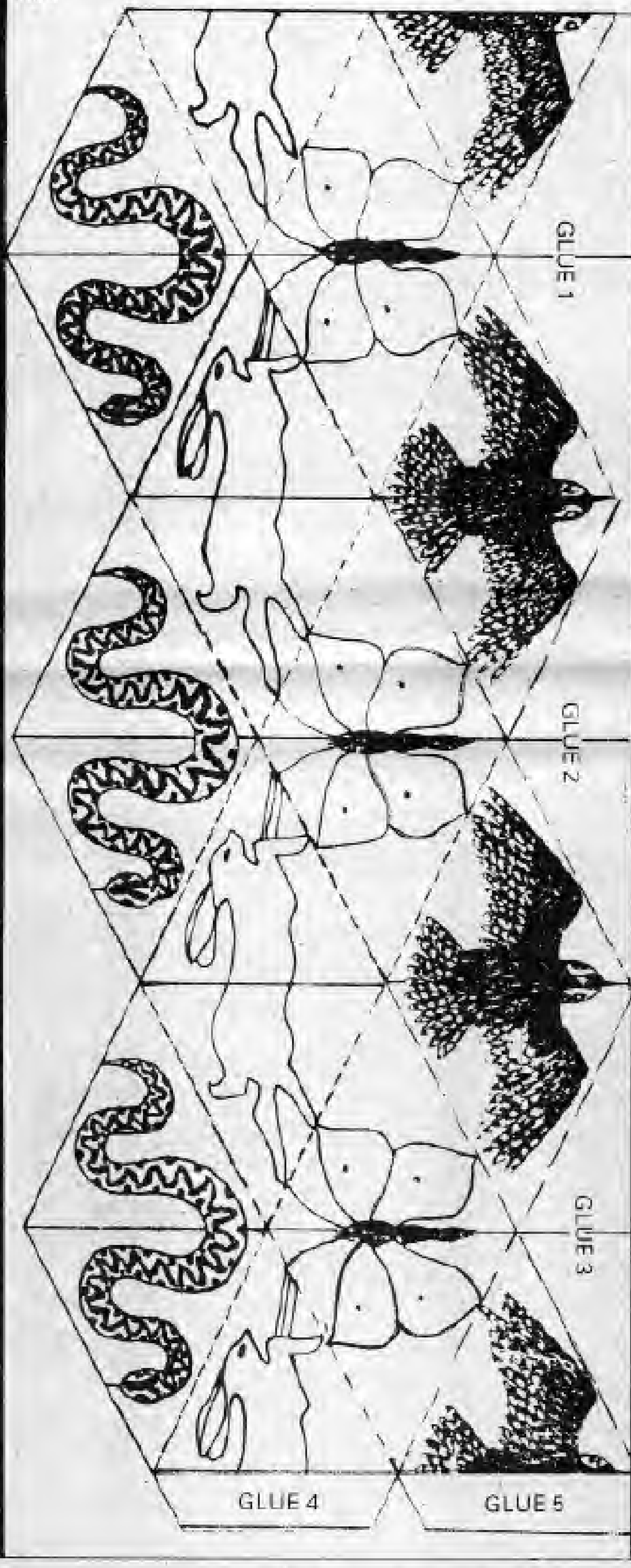
Early mathematics began with practice. It was used to solve practical problems in daily life. The first mathematicians were practical men — carpenters and builders. This fact has left its deep imprint on the very vocabulary of mathematics. For instance, what is a "straight line"? If you look up "straight" in the dictionary, you will find that it comes from the old English word for "stretched", while "line" is the same word as "linen" or "linen thread". A straight line then is a "stretched-linen-thread" — as anyone engaged in sowing vegetables or laying bricks knows only too well. This alone should suffice to show the real life links of mathematics.

Here we look at an enormously entertaining mathematical model. It belongs to a broad category called "flexagons" — so called because of their ability to be able to flex on their edges. In this model, six tetrahedra make a hexagonal ring which rotates through its own centre changing the pictures on its face as it goes. Mathematical models are in a sense applied mathematics. They also meet the universal human need to play. This one is simply irresistible. Once you've made it you'll keep flexing it endlessly.

How to make it?

Cut out the model (Fig 1) keeping well away from the outline. Stick it on a card sheet or a old drawing sheet and let it dry. Now cut along the outline accurately.

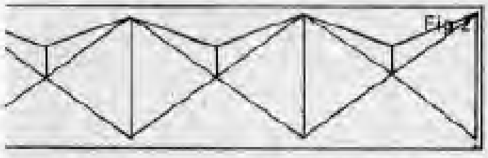
Fig 1



S Sampemane

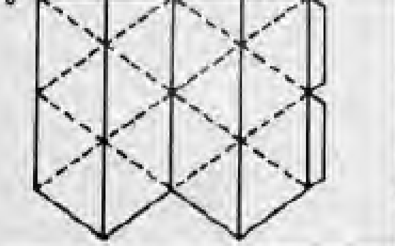
Score along all the fold lines — both dotted and solid. Now fold crease firmly using the straight edge or a ruler. Fold along the dotted lines away from you, and along the solid lines towards you. Stick them with an adhesive in the order 1, 2, 3, 4 and 5. After glueing flaps 1, 2

Fig 2



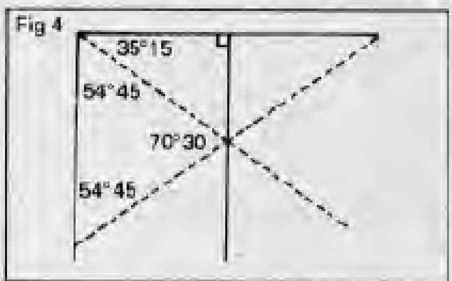
and 3 you'll get the shape shown in Fig 2. Now glue flaps 4 and 5 which go inside and complete the ring. Using an impact adhesive like Fevibond gives better results. Allow the model to dry before you start flexing it (Fig 3).

Fig 3



It is interesting to examine this model as it turns and to see what type of symmetry it has. You'll see that there are two positions in each rotation where the outline is a regular hexagon. With so much symmetry there are a number of ways to decorate this model. You might like to experiment further with new models. The net is not difficult to draw together with

Fig 4



the correct angles and is given in Fig 4. Any convenient size and any suitable card or drawing sheet will do. So get going on a joyous flexing spree. For more details you could consult the following books *Mathematical Delight* by W W Sawyer and *Mathematical Curiosities* by G Jenkins and A Wild.

ARVIND GUPTA

Mr Gupta is an IIT-Kanpur trained engineer. He has been associated with several educational and development groups and has written and traslated many popular science books and articles.

IN OUR FORTH COMING ISSUES...

- **WILL THERE BE ENOUGH FOOD NEXT YEAR?**
- **HOW AFRICA TACKLED ITS FAMINE**
- **"SEMIOCHEMICALS" IS THE TALK OF THE LIVING WORLD**

- **THE SUNQUAKES**
- **DEFUSING TOXIC THREATS**
- **SOAP BUBBLES AND POSTMEN'S BEATS**

LITTLE SCIENCE

Thorny tools

IT WAS a slightly thorny issue. But the little girl sorted it out. It happened during one of the botanical field trips of the Hoshangabad science teaching programme. While the others kids were busy ripping open flowers — prying into their stamens, stigmas, etc and dissecting them, this girl felt a bit left out — she had forgotten to bring her dissecting needle. However, necessity forced her to search for a substitute. And soon, she did find one, they were strewn around in plenty. The girl used a babool (*Acacia arabica*) thorn to do a beautiful dissection of the flower.

There is a moral in this true story. Adults have a lot to learn from kids. Children look at the world very differently, and given a little chance, often come up with the most original solutions.

Village fields have no barbed wire fences. Peasants normally fence their fields with the branches of the babool tree. For babool thorns being sharp and stiff constitute excellent defence armour against marauding cattle. That's why so many small birds — specially the bayas (weaver birds) who hang retort-shaped nests, find the babool tree a safe haven from big birds of prey.

Well, the little girl taught us how to make a babool thorn do some useful work — use it as a dissecting needle. You must have heard the common saying, "Use a thorn to pry out another thorn". We shall extend this idea a little further. Standing on one leg becomes a little painful after some time. So let's give the babool thorn another leg so that it can now "walk on two legs". We take two babool thorns of equal lengths, and insert their blunt ends on either side of a cycle valve tube piece (about 2 cm long). This flexible joint-of-two almost becomes a set of tweezers. We insert a third babool thorn at right angles to the valve tube joint. This thorn acts as a stem for purposes of holding. Now we slip in a piece of cycle valve tube on each leg of the tweezer and poke a fourth babool thorn cross-wise through these valve tubes. The addition of this crossbar stabilizes the tweezer — which earlier had a tendency of kicking its legs apart. The pointed end of the holding stem is anchored to the centre of the crossbar with another piece of valve tube.

With two legs and a crossbar the assembly takes the familiar shape of the letter "A". The triangle in this "A" shaped structure makes it rigid. In the article on the "matchstick meccanno" (SCIENCE AGE Sept 1985), we have learnt that the triangle is the only rigid polygon.

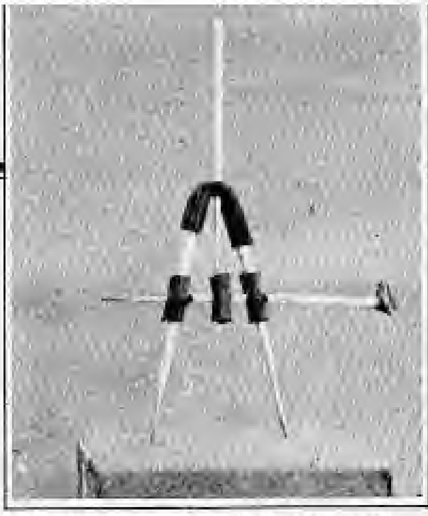
These four babool thorns in the form of two legs, a crossbar and a holding stem, assemble together to make a divider. The points of this babool thorn divider are even sharper than some of the dividers available on the market. The distance between the two legs of the divider can be adjusted — that is increased or decreased by sliding them on the crossbar.

This divider can easily be converted into an ink compass. Take a ball pen refill in which the ink is just about to finish. Cut the plastic refill at about an inch from the brass tip and insert it in one leg of the divider. You may have to cut away the sharp end of the babool thorn in which you insert the refill. You can draw inked circles using this compass.

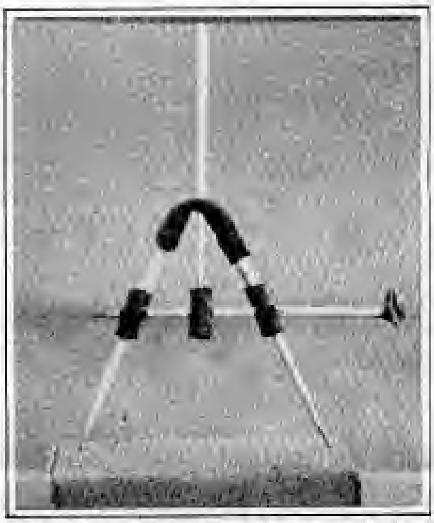
Children need to learn skills in handling tools like scales, dividers, etc. If, however, the children are involved in making the tools themselves, they are much more at home with them. Children use these tools — the fruits of their labour—with much more respect and reverence. Apart from gaining further mastery and adeptness in using them, children can also repair them if they have to.

ARVIND GUPTA

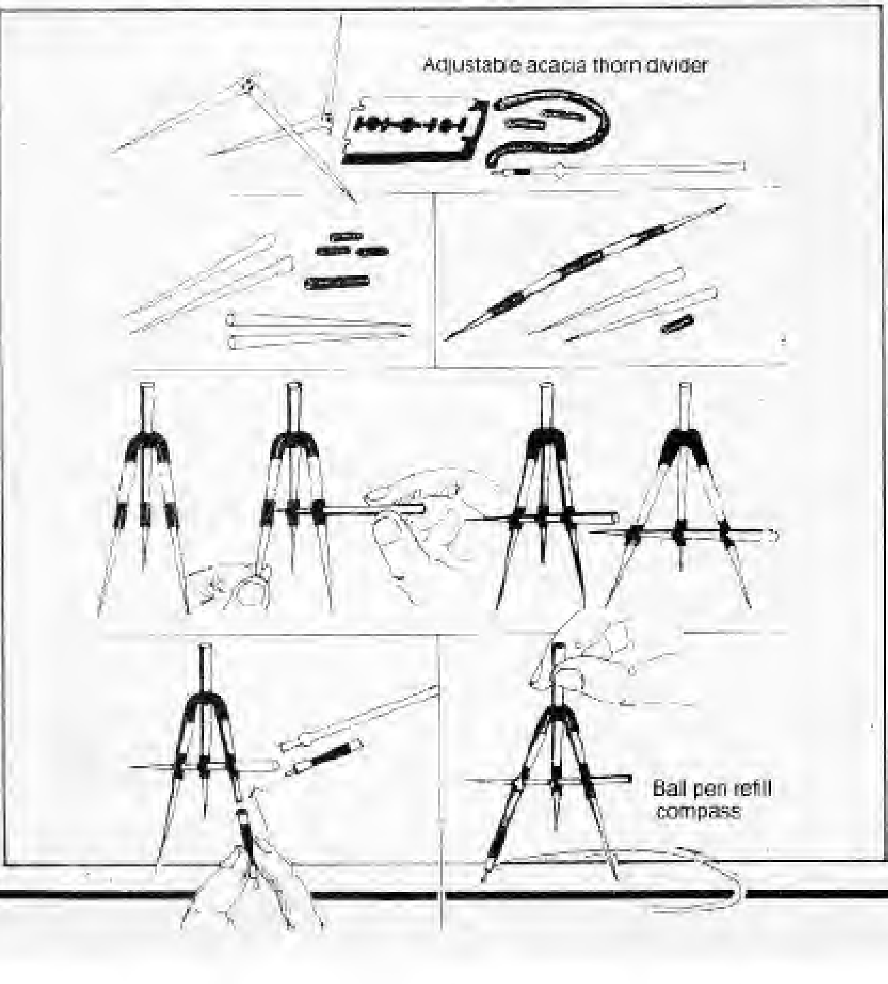
Mr Gupta, an electrical engineer is involved with popular science movements.



Babool thorn adjustable divider (retracted)



Babool thorn adjustable divider (expanded)



How to tackle a pulley

YOU CAN only "pull" at a string, you can't "push" it. For strings work only in tension and not in compression. A device which changes the direction of this "pull" is called a pulley. Though by nature a passive device, a pulley can be used to advantage to ease a lot of hard toil. So lets trot over to the nearest pulley to see it in action.

A well not so well

Let's look at a single fixed pulley atop a well. Many village wells don't even have a creaky pulley. And not all is well with such a well. For it's a painful task drawing water from a well without a pulley. This is because the pulling-up of the rope is a very inconvenient direction in which to exert force. However, with a pulley above the well the rope can be pulled down at a convenient angle. The task becomes easier in this position because a part of the body weight can be gainfully deployed for lifting the bucket of water.

The fixed pulley on the well has merely changed the direction of the pull. The mechanical advantage is still one. Which means that the effort required in this case is at least equal to the weight of the pulley.

Movable pulley

You can, however, use a single pulley to magnify the force you exert. This is done by having a movable pulley instead of a fixed one. Notice in Fig 1 that the pulley is not fixed, and that the rope is doubled as it supports the 100 kg barrel. When rigged in this way a single pulley is called a runner. Each half of the rope carries one half of the load or 50 kg. Thus by using a movable pulley, a man can lift a 100 barrel with a 50 kg pull. The mechanical advantage is two. The single movable pulley in this set-up is really a second class lever (see Fig 2). Your effort E acts upon the arm EF which is the diameter of the pulley. The resistance R acts downwards on the arm FR, which is the radius of the pulley. Since the diameter is twice the radius, the mechanical advantage is two. But, when the effort at E moves up two metres, the load at R is raised only one metre. That's one thing to remember about pulleys and blocks and tackles—if you're actually getting a mechanical advantage from a system, the length of string or rope that passes through your hands is greater than the distance that the load is raised. However, because you can lift a big load with a small effort, you don't care too much about how much rope you have to pull. The saying that "many hands make light work" is best exemplified in movable pulleys.

The man in Fig 1 is in an awkward position to pull. If he had another pulley handy, he could use it to change the direction of the pull as in Fig 3. Because the second pulley is fixed, it merely changes the direction of pull, but the mechanical advantage of the whole system remains two only.

Pulleys can be arranged in a number of ingenious configurations to get different mechanical advantages for doing different jobs.

The results can now be summed up. With a single fixed pulley the only advantage is the change in the direction of the pull, the mechanical advantage is still one. A single movable pulley gives a mechanical advantage of two. Many combinations of single, double and triple pulleys in fixed and movable set-ups can be rigged up to give greater mechanical advantages.

Cotton reel pulleys

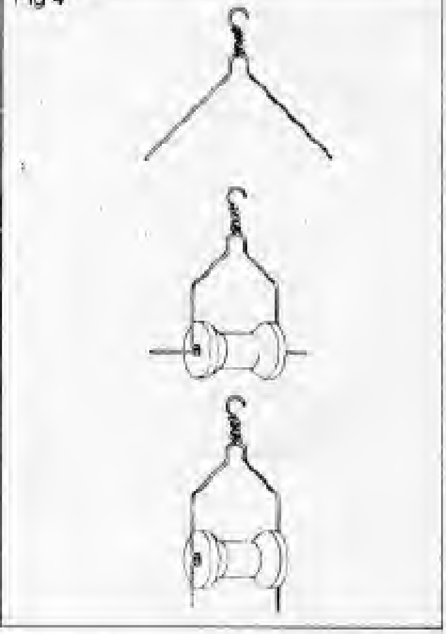
A reasonably satisfactory pulley can be made from a wire clothes hanger and a cotton reel (see Fig 4). Cut off both wires of the hanger at a distance of about 20 cm from the hook. Bend the ends at

Fig 1

Fig 2

Fig 3

Fig 4



right angles and slip them through the opposite ends of the reel. Adjust the wires so that the reel turns easily and then bend the ends down to keep the wires from spreading.

Button pulleys

Cotton reel pulleys are a trifle heavy for doing experiments. An ideal pulley should have a zero deadweight—a feat impossible to achieve in practice. However, you can make very lightweight, smooth and efficient pulleys using buttons at a very low cost. Two buttons put back-to-back make the pulley, and a paper clip makes the hanger (see Fig 5). Take cheap quality plastic coat buttons in which you can make a hole with the tip of a hot needle. Take two such coat buttons and rub their surfaces on the cement floor to remove any burrs. After mating their flat surfaces sew the buttons together with a needle and some thread. Remember to sew the two buttons in the form of a square. Avoid taking cross stitches as they will mask the "centre" of the buttons. The two buttons anchored back-to-back take on a profile of a pulley. Now heat the tip of a long needle in a candle flame. Insert the hot tip of the needle axially through the buttons. With a little practice you'll be able to make a well-aligned and smooth bore.

The hanger for the pulley is made using an ordinary paper clip. Open up a paper clip into an S shape. This S also makes a good hook for suspending objects. Bend horizontally one leg of the S and insert in it the double button pulley. Insert a small cycle valve tube "stopper" to prevent the pulley from slipping out. The top kink of the paper clip hanger can now be hung by a nail.

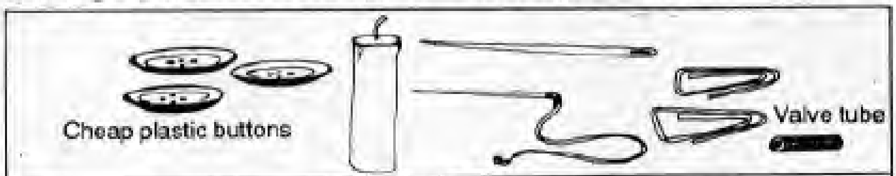


Fig 5

Fig 6

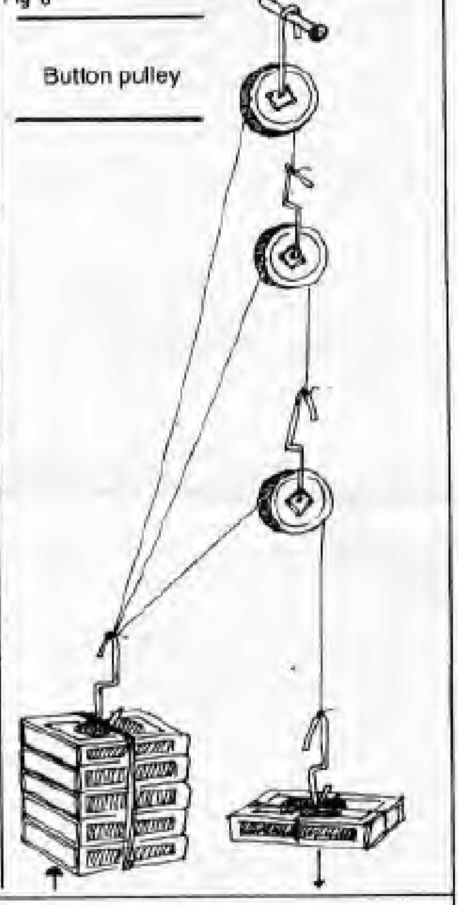
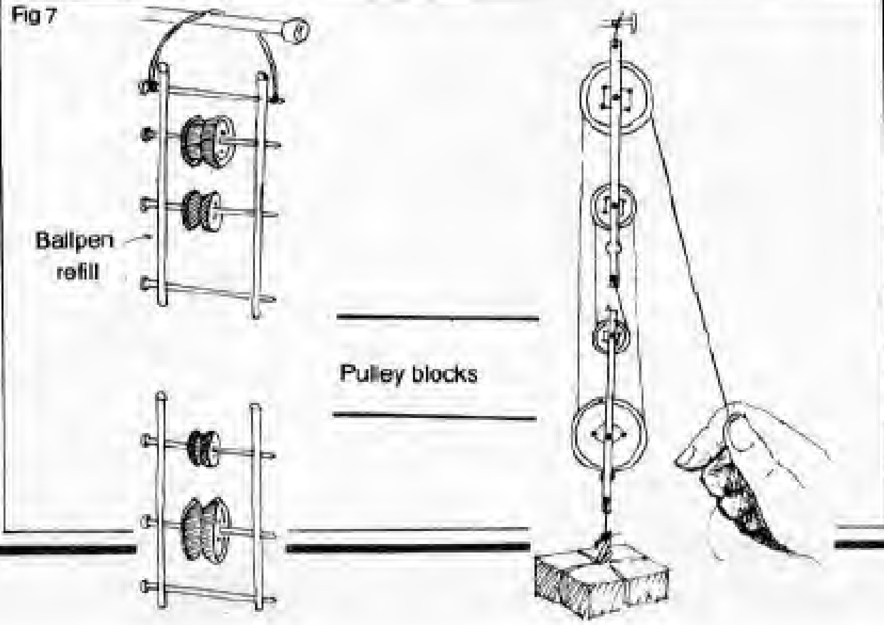


Fig 7



Avinash Deshpande

Three button pulleys

Fig 6 shows a particular arrangement of three button pulleys. Rigged in this manner, one new matchbox (weight approx ten gm) on the effort side is able to lift up five new matchboxes (weight approx 50 gm), on the load side. Theoretically the mechanical advantage of this whole system is seven. But you can practically demonstrate a mechanical advantage of five.

Multiple pulleys

Big-diameter pulleys can be made using large coat buttons. Small pulleys are made by using pant buttons. Multiple and differential diameter pulleys can be made by assembling co-axially several pulleys. Pulley blocks of different sizes can be made by assembling button pulleys in ladder-shaped hangers. The long members of the ladder hangers are made of used plastic ballpen refills and the steps are made by inserting paper pins. The button pulleys rotate on the pin axles (see Fig 7).

Button pulleys are very versatile and can be used in scores of physics experiments like equilibrium of forces, block-and-tackle trolley on an inclined plane, to mention a few. Button pulleys can also be mounted on shafts of battery-operated toy motors for transmitting drives. You'll certainly find many more creative applications for the button pulleys in making model cranes and winches.

ARVIND GUPTA

Mr Gupta, an electrical engineer, has been involved with People's Science Movements. At present he is on a Department of Science and Technology fellowship writing a book on matchstick meccano and other science experiments.

You'll find it all matches

ANY MECCANO, even of the most expensive sort, when stripped of its frills and fancies, essentially reduces to a few basic building blocks and couplings. These basic building blocks and couplings can be joined in a variety of ways to create an array of different structures and configurations.

The matchstick meccano is much more versatile and organic than the commercial kind. It uses matchsticks as the basic structural members and bits of cycle valve tube as joints and couplings. Cycle valve tube is readily available and is sold by weight in cycle shops. A 100 g packet of valve tube costs Rs 5 and contains about 20 metres of tubing.

With valve tube rubber joints to which 2, 3, 4, 5, 6, matchsticks could be affixed, this meccano provides a great deal of design latitude and flexibility in model making.

Though at first sight the models may appear fragile, they are indeed fairly strong. This is because all the joints are made of shock absorbent rubber tubing. Because of this property the models bounce back when chucked against a wall.

Angles

Cut about 1 cm long pieces of the cycle valve tube. With a blade scrape the sulphur from the matchstick heads. Now push a matchstick halfway through the valve tube. You'll find that the matchstick end slides snugly inside the valve tube. Through the other end of the valve tube insert a second matchstick.

This is a joint of two matchsticks, or simply a joint-of-two. It's a flexible joint and can be used for making acute angles, right angles and obtuse angles.

Join three matchsticks and three valve tubes in a row. Loop this assembly together to form a triangle. As the matchsticks are the same length the triangle turns out to be equilateral — with all its sides equal. All the angles of this triangle would automatically be equal and measure 60 degrees. This gives a concrete feel for a 60 degree angle.

Other shapes, like isoceles triangles, squares, rectangles, pantagons, hexagons and octagons, can be made by joining together more matchsticks to more valve tube pieces. In this way a whole range of polygons can be made.

Arrange sets of similar polygons or their combinations into different layouts so as to generate new patterns.

Triangles are rigid

Try pressing a pentagon between your thumb and the middle finger. What happens? The pentagon caves in, distorting from its initial shape. Try doing the same thing with the hexagon. The hexagon also changes shape.

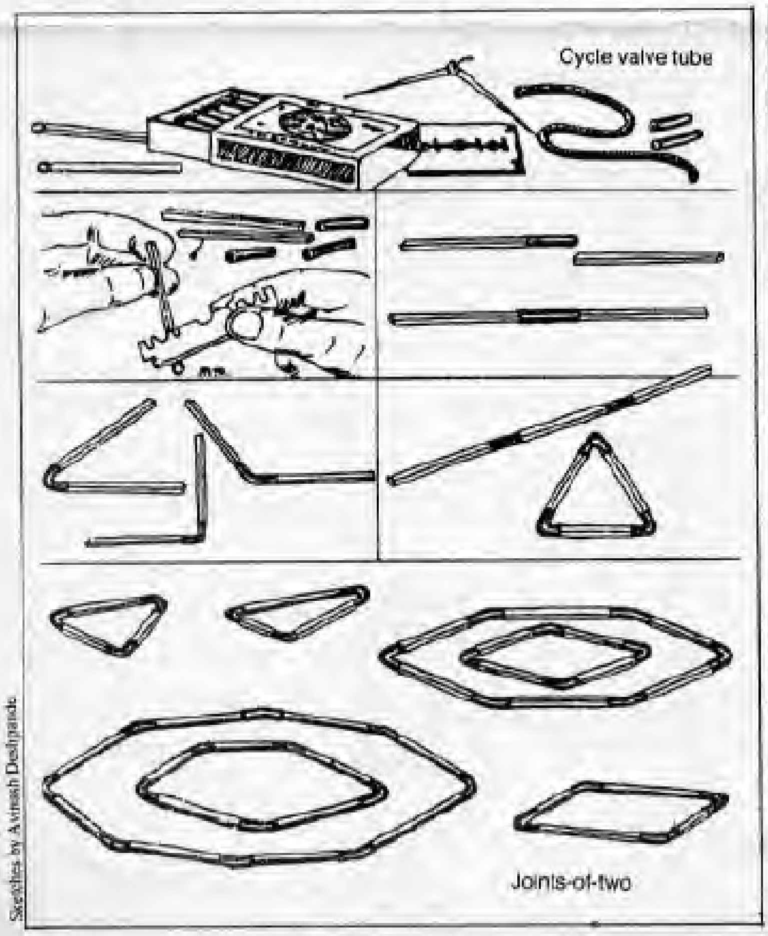
Now hold opposite sides of the square and try pressing it. What happens? The square is unable to resist the pressure. Its right angle gives way and distorts into a rhombus.

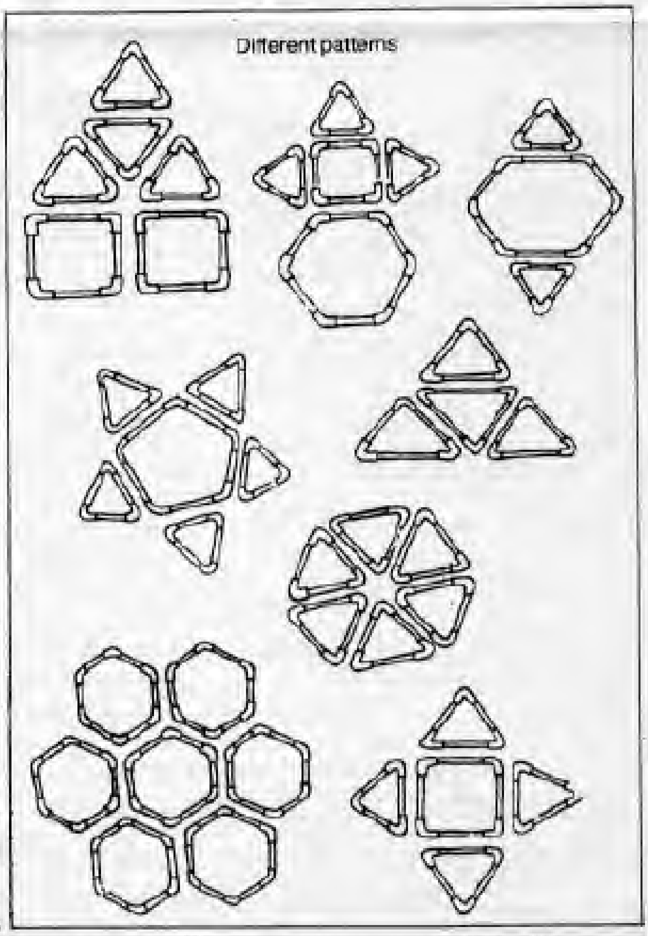
Finally, try pushing the triangle. What happens? It does not budge at all. Its shape remains unaltered. The triangle remains a triangle.

The triangle is the only rigid polygon.

You must have often seen steel girders and beams across railway bridges and river streams. The bridge trusses are always divided into triangles. What would have happened had they been divided into squares or pentagons?

We have just seen how stable and rigid the triangle is. What can be done to make "dancing shapes" like the square rigid? Simply divide the square into two triangles





by adding on a diagonal element.

To do this simply pierce a long babool thorn or a needle (preferably a long one) through the diagonal rubber valve tube joints of the square. Does the square still wobble? Why? How will you now convert the pentagon and the hexagon into rigid shapes?

Joint-of-3 or T-joint

Pierce a hole in the valve tube joint-of-two, by poking it at right angles with a babool (acacia) thorn. Push a third matchstick (slightly sharpened at the end) in this hole. This is a joint-of-three, or a T-joint. Take the equilateral triangle which you have made earlier. Poke holes in its valve tube joints with the babool thorn. Now push the three matchstick legs of the joint in the holes of the triangle. For ease of entry slightly sharpen the ends of the matchsticks in the T-joint.

A new structure takes birth. It has four corners, 6 edges and 4 distinct surfaces. All its surfaces are equilateral triangles. Triangles, we have just discovered, are rigid shapes. So we can presume that a structure made up of equilateral triangles should be a rigid structure too. And it turns out to be true. This structure is called the *tetrahedron* (meaning made up of four triangles) and is the most fundamental structure found in nature.

In a similar manner we can join two separate triangles with 3 matchstick legs, thereby making a *prism*.

Two separate squares joined together by 4 matchsticks would make a *cube*.

You can make many more structures using the joint of three.

Joint-of-4 or X-joint

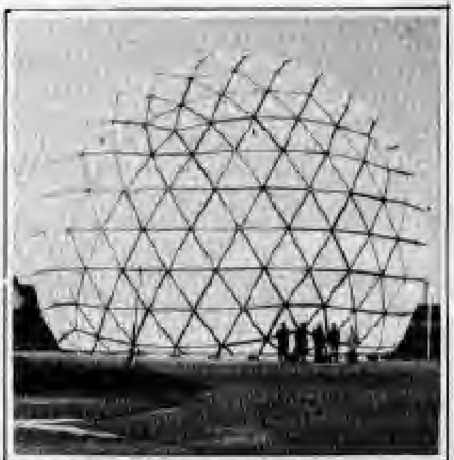
Cut two pieces of valve tube, each about 2 cm long. Push a babool thorn through the hole of one valve tube. The thorn acts as a spindle and provides rigidity to the rubber valve tube. Now place this thorn at right angles to the length of the second valve tube and pierce it through its centre. Now hold the thorn vertical with its broad end resting on the floor. Pull both the ends of the second valve tube (this stretches its hole) and slide it over the first valve tube. Now gently remove the valve tube cross joint from the thorn. This is a joint-of-four. Fix four matchsticks in this X-joint.

Pick up the square which you had made earlier. Poke holes in its valve tube joints with the help of a babool thorn. Fix the four matchsticks legs of the X-joint in these holes.

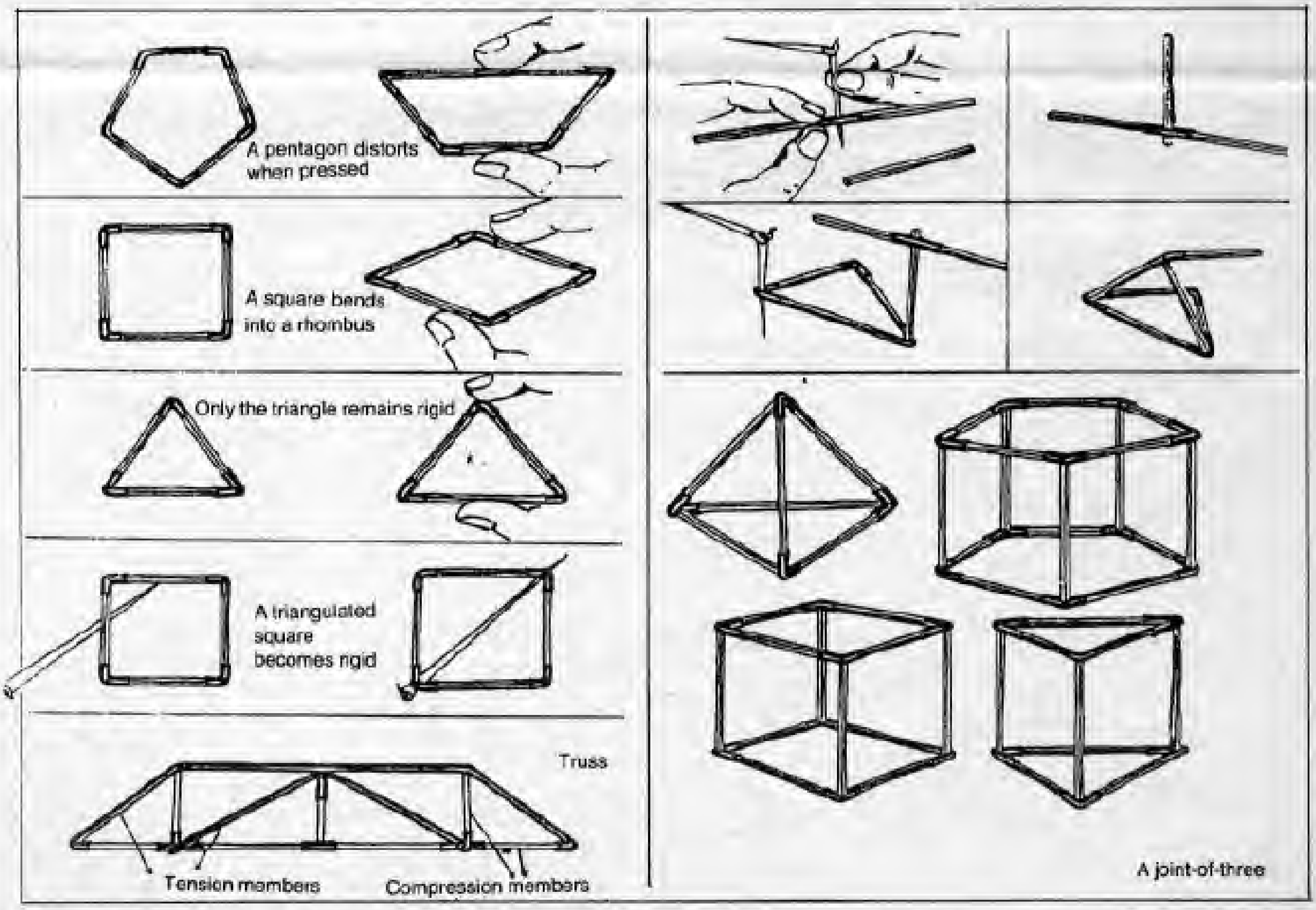
This new structure is a *pyramid*. Its apex is a joint-of-four. Make more structures like the *octahedron* using joints-of-four. For the octahedron you will require 6 joints-of-four and 12 matchsticks.

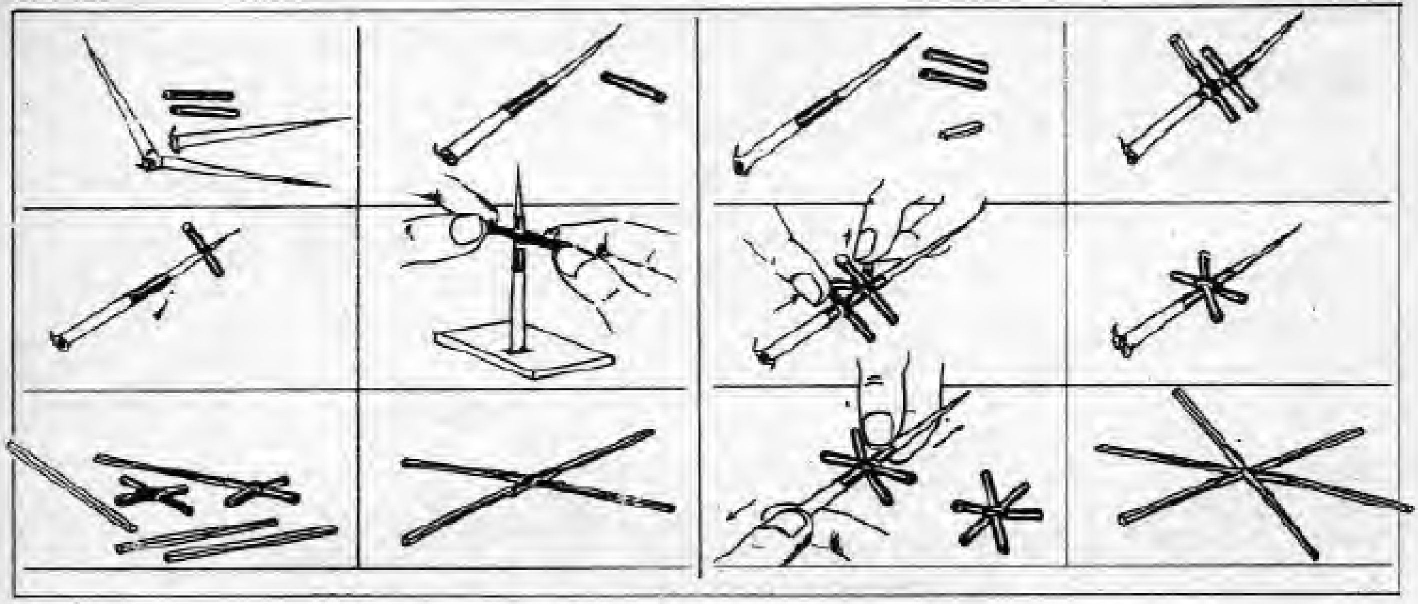
Star joint

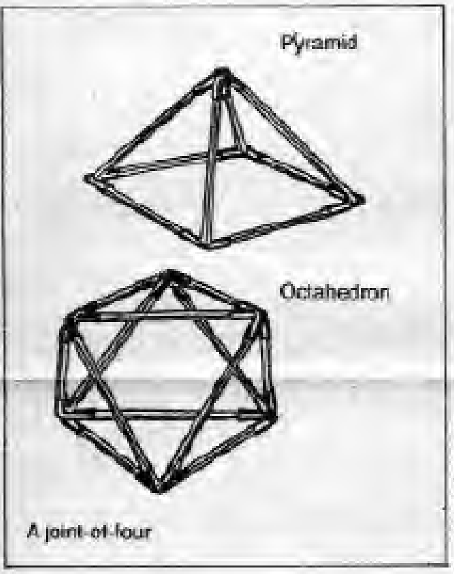
Make a joint-of-four as described in the previous section, but do not remove it from the babool thorn. Like the second valve tube, slide a third valve tube crosswise over the first. The second and the third valve tubes are now at right angles to the first. Thus we get an H shape. Insert a small piece of matchstick in any of the free legs of the H. Sharpen the ends of the matchstick, and weave it through the centre of the other leg of the H. After removing the babool thorn phase out the six legs of the valve tube star so that they



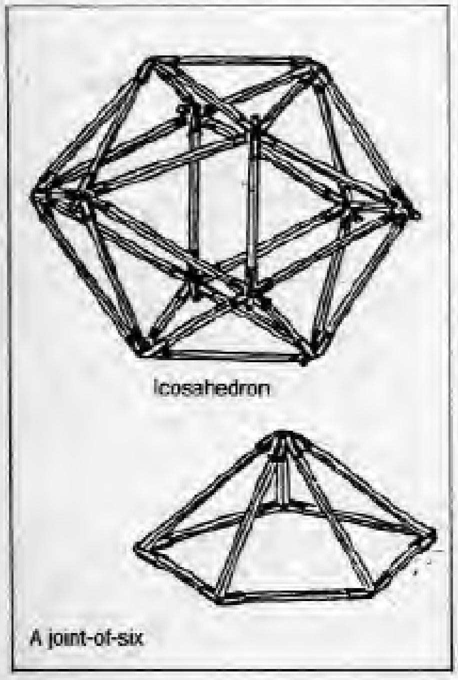
A geodesic dome; an igloo made of triangles







A stable and efficient packing



are approximately 60 degrees apart. For a joint-of-five, cut short one of the legs of the H.

Using the joint-of-five make an *icosahedron*. For this you will require 12 joints of five and 30 matchsticks. See whether you can flip in the pentagonal phases of the icosahedron by pressing them inside.

Basic modules

Apart from the triangle there are only three other basic structures which are stable, triangulated and symmetrical — the tetrahedron, the octahedron and the icosahedron. All the structures that you have made can themselves be arranged together in different combinations and configurations to generate newer structures. For example, when the prism is kept on top of the cube it becomes a house. Several such combinations will provide you with hours of entertainment.

For making larger models you can substitute the matchsticks with short and equal pieces of cycle spokes.

A geodesic dome can be made using matchstick members and joints of six. This kind of dome is basically a triangulated hemisphere — an igloo made of triangles.

The beauty of the tetrahedron

If you had a few marbles how would you arrange them so that they occupied the least amount of space?

Well if they were just two you could just keep them side by side. If, however, there are three marbles, you can put them in a straight row. But this arrangement is expensive. The closest pack of three marbles is when they are arranged in a triangle.

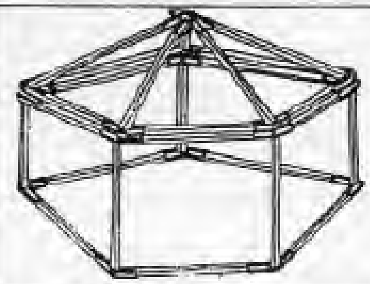
It turns out that four marbles are most closely packed if the fourth marble is placed over the valley formed by the earlier marble triangle. When four marbles are arranged in this manner they basically make a tetrahedron.

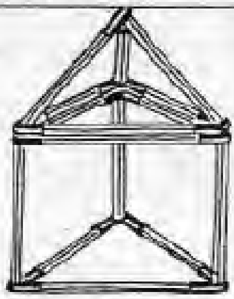
This close packing nature of tetrahedrons has always been used to advantage by working people, long before scientists discovered it. For instance, fruitsellers always have their oranges packed in neat tetrahedrons. So are the near spherical laddus in halwais' shops.

In the grain market, the big balances to weigh heavy sacks are suspended from the top of a bamboo tripod — which is essentially a tetrahedral structure.

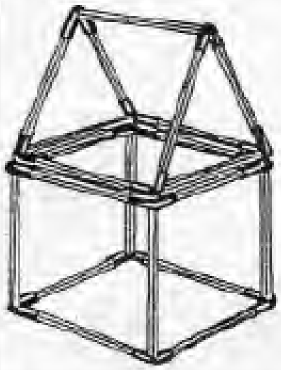
Molecular structures

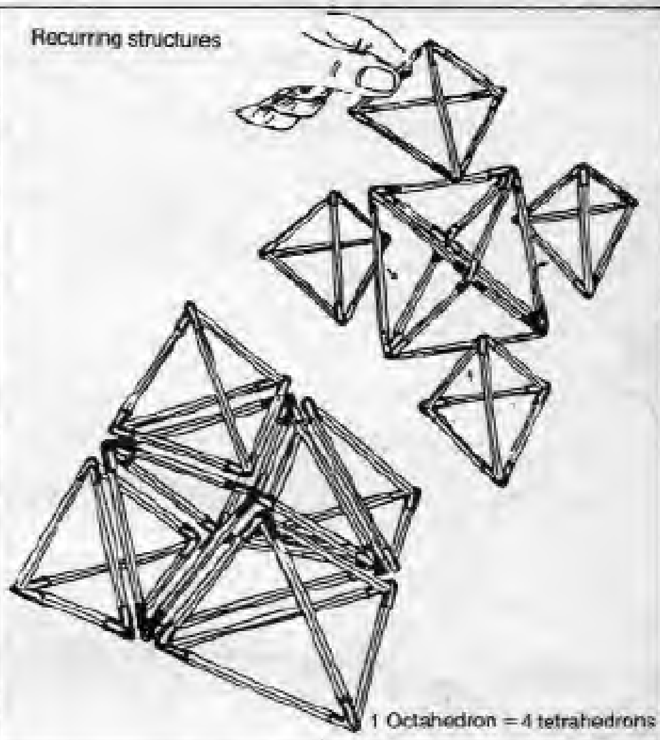
A number of simple molecular structures can also be made using the matchstick valve tube meccano. For instance, four marbles can be neatly inserted into the tetrahedron. The resulting structure becomes the molecular structure for "methane" — which is the major constituent in gobar gas. The chemical symbol of methane is CH_4. Here the four atoms of the hydrogen are at the four apexes of the tetrahedron, and the lone carbon sits in

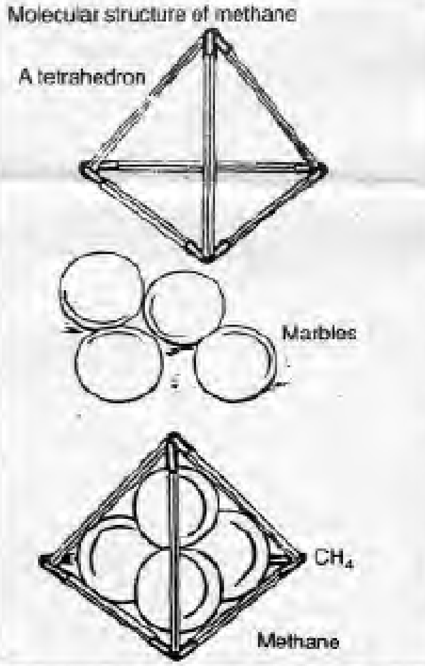




Different arrangements of basic modules







Fruits stacked is a neat tetrahedron

1 octahedron = 4 tetrahedrons

the space between the four hydrogen atoms.

Similarly other molecular and lattice structures can be made.

Octahedron-tetrahedron complex

When four equal tetrahedrons are grouped to define a larger tetrahedron, the resulting space is an octahedron. You can actually make a larger tetrahedron using four small tetrahedrons and one octahedron. If the volume of the small tetrahedron is one (edge-length — one matchstick), then the volume of the larger tetrahedron (edge length — two matchsticks) is $2\times 2\times 2 = 8$ times the volume of the smaller tetrahedron. Thus the volume of the octahedron can be empirically calculated as $8 - (4 \times 1) = 4$.

Similarly, a cube may be formed by placing four 1/8 octahedrons with their equilateral faces on the four triangular faces of the tetrahedron. Since, tetrahedron $= 1$, and $1/8$ octahedron $= 1/2$, therefore, the value of a cube is $= 1 + (4 \times 1/2) = 3$.

So if the tetrahedron has a volume of one, the octahedron has a volume of four, and the cube has a volume of three.

That is very interesting, because if you try accounting in cubes for nature's give-and-take and constructions — as structural systems — you use up three times as much space as you do if you count space volumes in tetrahedron units. Since nature always economises, it never uses cubes for its structuring. If you use tetrahedrons as your co-ordinating system, something very economical and fundamental happens. The cube's angles are all 90 degrees. When you want to make a bigger cube out of little cubes — want to double the size of the cube—you then put eight little cubes together and get them closely stacked around a point. The edges of the big cube are two units long (if the small cube has a unit edge). So it is possible to build only third power models using cubes.

By using 60 degrees co-ordinate systems, you can put 20 tetrahedrons around one point instead of the eight cubes. Two to the fourth power is sixteen, and there are 20 tetrahedrons around a point. It is possible, then, for school children to make fourth and fifth power models with tetrahedral and octahedral building blocks.

Mr Gupta, an electrical engineer is involved with popular science movements., The matchstick meccano was developed by him as part of the Hoshangabad Science Teaching Programme aimed at activity-based science teaching for village children.

INFO DESK

How did they measure the circumference of the Earth nearly two thousand years ago?

WELL SURELY not by on-the- spot surveying? The Earth had not been circumnavigated yet — a feat Magellan was to perform nearly 1500 years later.

Those who believe that the ancients — or the heirs of extraterrestrial visitors — had a much more advanced technological civilisation than even our present one, would object to these statements! But they stand nevertheless.

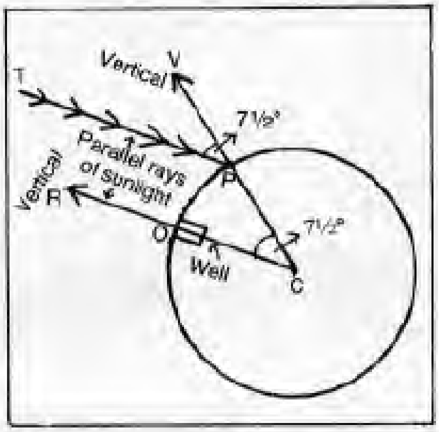
Even then measuring the Earth on the spot was a problem. Surveying on land is difficult enough. Try putting up markers on a choppy sea surface.

Perhaps in those troubled times any attempt to measure theEarth on the spot would have come up against hostile tribes and pirates as did the attempt to measure the Parisian meridian at the time of the French revolution. (The revolutionary government had decreed that the "defined" meter would be a 10 millionth part of the North pole to equator part of the Parisian meridian.) Presumably there were quite a few cannibals around too.

Yet the ancient sages of Egypt which was a prominent seat of Greek civilisation then managed to measure the circumference of the Earth fairly accurately for it's time. How? By keenly observing a popular fable.

The fable was that at a deep well near present day Aswan a strange thing happened once a year. Only once in a year could you see the Sun — at noon — from the bottom of the well. The well presumably had steps for descending to the water surface. It did not take long for the observers to note that the sighting of the Sun always took place on the longest day of the year. (That is around 21 June of our present calendar). On all other days the Sun was always a bit to the south of the vertical — as it is for New Delhi and more northerly towns of India, throughout the year.

It should be clear by now to our readers — though the ancients did not realise then — that the particular well was located on the tropic of Cancer. (It passes very near Ahmedabad) The ancients also knew that on the same day — at high noon — at a place near Alexandria — 800 kilometres to the north — the Sun stood nearly 7½ degrees to the south. (Of course people did not then measure in terms of kilometres. The units of length in common use were the stadia — we have converted the distances to modern measure for you.)



The sages then argued thus: First, the Sun is very, very far away from the Earth. So we can say that the Sun's rays coming to us may all be regarded as parallel. Second the Earth is spherical in shape. (The ancients were already navigating the relatively tranquil Mediterranean sea. It had no tides. The observation of approaching and receding sailing vessels convinced them that the Earth was really spherical). Third, any section of a sphere is a circle. This fact was known to the ancient geometers.

So they drew the following diagram to illustrate the sighting of the Sun from the well and the place 800 km north.

C is the centre of the Earth. Hence COR and CPV are "local" verticals. TP and RO are the parallel sun rays. P is to the north of O and arc OP = 800 kms. The angle VPT is observed to be 7½° and so is the corresponding angle (hypothetical) VCO at the centre of the Earth. The 7½° arc is 800 kms. Clearly the circumference, which is a whole arc should subtend an angle of 360° at the centre. By the simple "rule of three" (proportion) the circumference comes to be 360/7½ × 800 km

= 48 × 800 km

= 38,400 km.

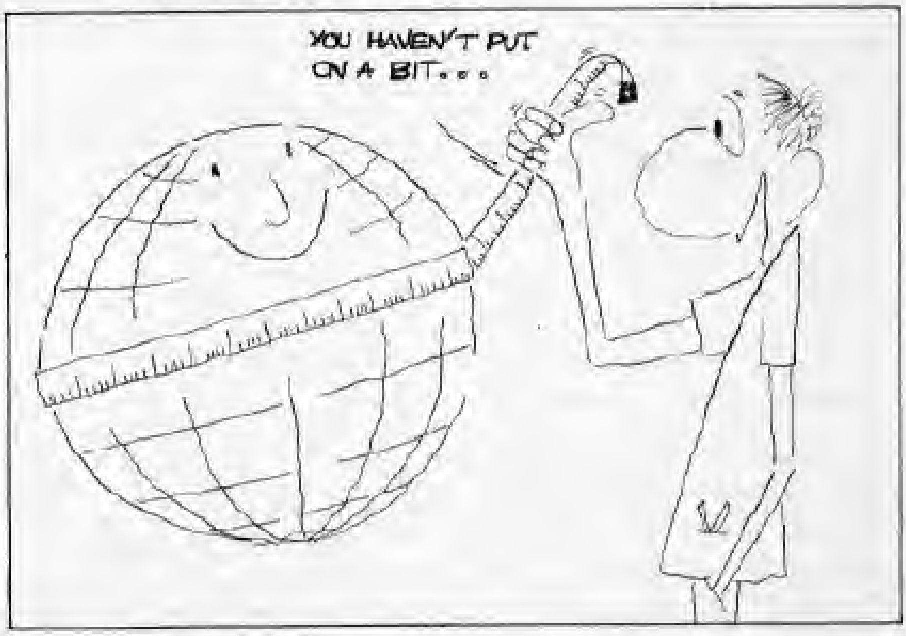
Simple isn't it?

Of course the result is slightly incorrect. The true value is close to 40,000 km. The ancients did not have instruments accurate enough for sighting — neither telescopes nor sextants. However, in the centuries following,people built huge fixed structures like the observatory at Jaipur. The massive sextant near Samarkand allowed the royal astronomer Ulugh Beg to produce tables which were more accurate than those of Tycho Brahe (See SCIENCE AGE, August 1985).

By then the circumference of the Earth and hence the Moon's distance from the Earth and the diameter of the Moon were fairly accurately calculated by geometry and trigonometry. Galileo could then use these results to calculate the height of mountains on the Moon. (They are taller than Everest!)

But that is a story for another Info desk.

J R KARHADKAR



Soap films

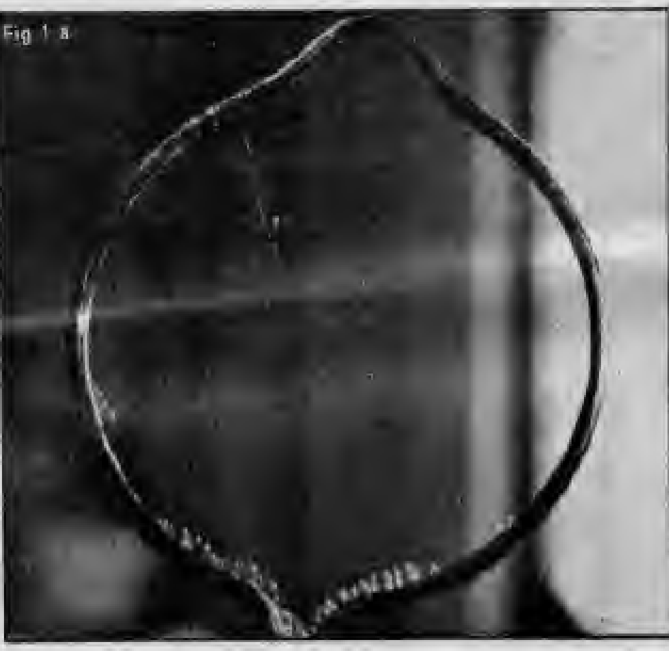
SOAP BUBBLES and films are fascinating; they have also been used to solve some practical problems. Consider, for instance, a postman who has to deliver mail in three villages everyday. Rural roads being bad he is free to cut across fields and make his own path. How best can the postman minimize his beat?

Minimum surfaces

Soap films form minimum networks. This can be easily demonstrated by a simple experiment as in Fig 1. Here, a small loop of thread is supported on a soap film stretched across a metal ring. Pricking the film in the centre of the loop causes the film around the outside to pull the loop open to make a perfect circle. The hole inside the loop becomes as large as possible and circular, because the film around its outside becomes as small as possible. The soap film opens out the thread loop just as firemen hold open a rescue net — by pulling outwards in all directions.

Fig 1

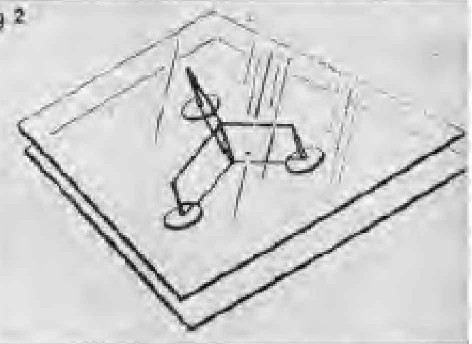
Fig 1 a



Triangular beat

The problem of the postman and the triangular beat can be simulated by taking three drawing pins (thumb-tacks) and placing them between two glass sheets (or clear plastic perspex sheets). If an entire sandwich of glass and drawing pins is dipped into a soap solution and then withdrawn, soap films clinging to the pins join in a three-way corner (Fig 2). This triple junction is depicted in Fig 3(a), the three dots representing the three pins and the three lines meeting at 120° represents the cross-sections of of the three vertical films. The interesting fact is that when the three films meet at 120°, they use less material than they would if they came together in any other way. With a little plane geometry you can easily prove that the films have 58 per cent of the length they would have if they travelled directly from pin to pin around the perimeter as in Fig 3(b). Thus the three-way 120° junction uses the least material.

Fig 2



Let us experiment further with the drawing pin sandwich. What happens if the triangle has unequal angles. In the triple junction we observe a general rule — the junction moves towards the pin that sits at the vertex commanding the largest angle. Furthermore, we observe that when the triangle outlined by the pins has a vertex with an angle of 120° or more, the triple junction degenerates and joins the pin that marks the vertex (Fig 4).

Square beat

Now let us add a fourth pin to the sandwich. If the pins sit at the vertexes of a square, we might expect the partition to meet at a central four-way junction, as depicted in Fig 5b. Indeed that system of partition uses 94 per cent of the material that would be used to enclose the square on three sides, as shown in Fig 5c. However, if we withdraw the four pin sandwich from the soap solution, the film adopts a still more economical picture (Fig 5a). This system of two triple junction uses 91 per cent of the material of Fig 5c. Though a double, three-way junction, and a single four-way junction are not very different, representing 91 per cent of the three sides of a square, yet the soap films unerringly choose the one with the least material.

Fig 3

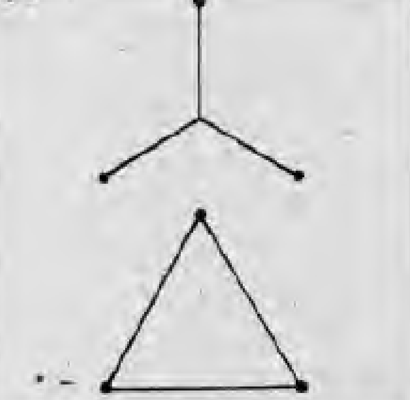


Fig 4

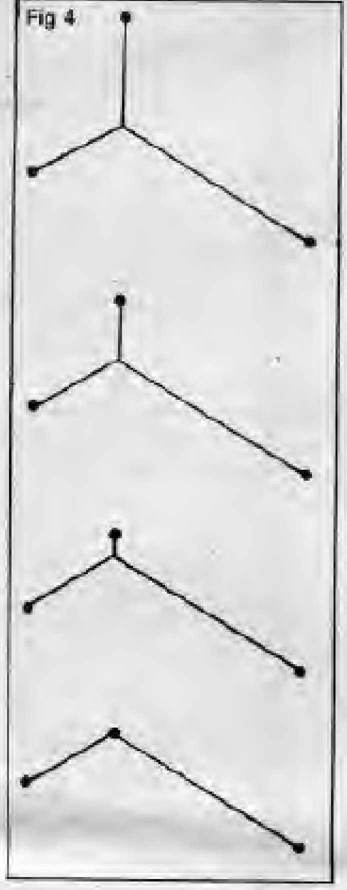


Fig 7

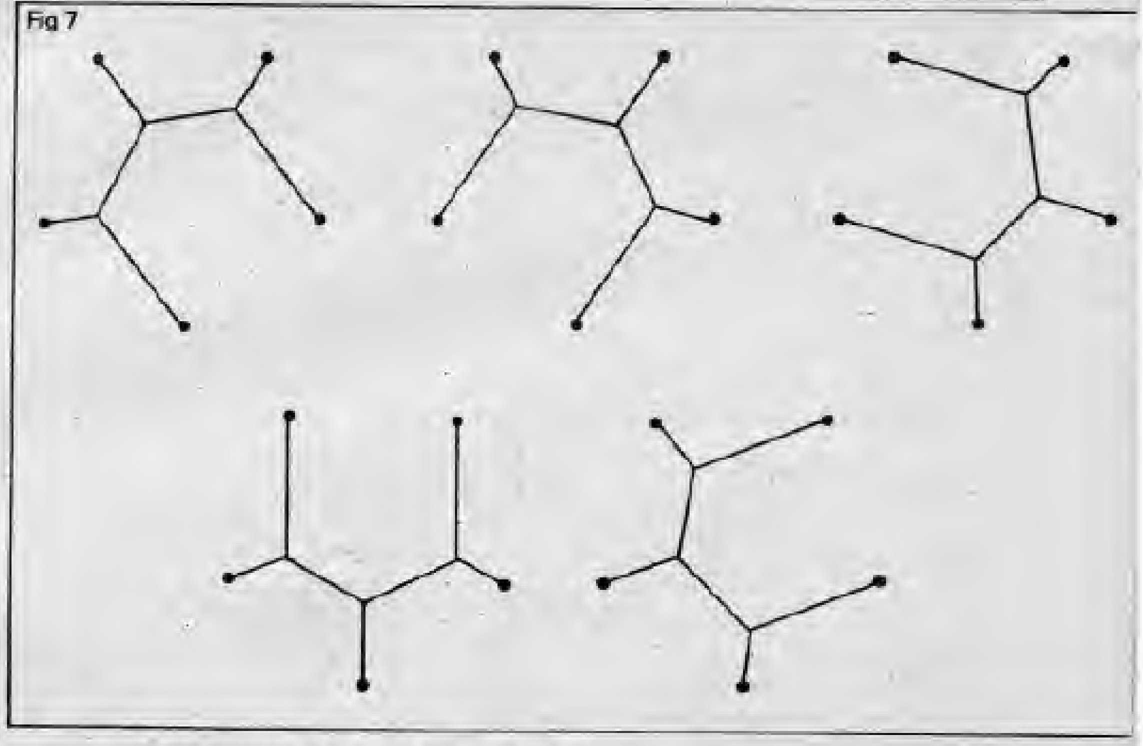


Fig 5

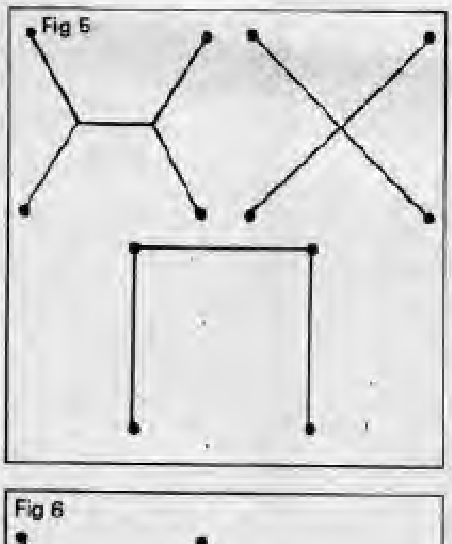
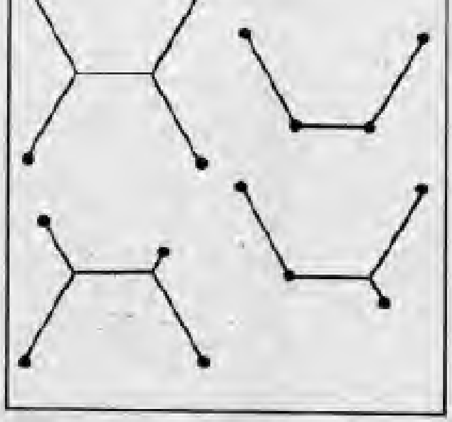


Fig 6



What happens if the pins are arranged in an irregular quadrilateral instead of a square? In this case too, the triple junction moves towards the largest angle of a quadrilateral. Fig 6 makes clear the movements and the degeneration of the two triple junctions as the four drawing pins are moved.

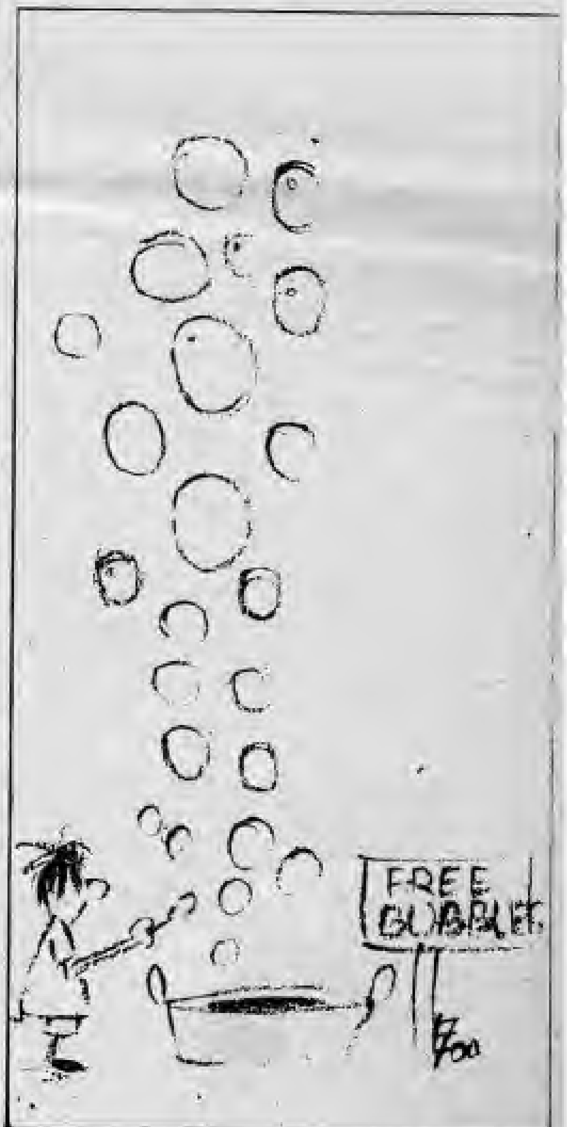
Pentagonal beat

Uptill now we have used four drawing pins in the sandwich. Suppose we add more. A regular arrangement of five pins gives rise to three triple junctions and the network of films can adopt any of the five positions shown in Fig 7. If we keep increasing the number of thumb-tacks and study their networks,soon a pattern begins to emerge. The triple junction emerges as the stablest. The number of drawing pins (or points) minus the number of triple junctions is always equal to two.

Thus the property of soap films to form minimum surfaces can be used empirically to obtain elegant solutions to some practical problems. For more details you could consult Soap bubbles by C V Boys, and *Patterns in nature* by Peter S Stevens.

ARVIND GUPTA

Mr Gupta is an IIT-Kanpur trained engineer. He has been associated with several educational and development groups and has written and translated many popular science books and articles.



Bharat Jan Vigyan Jatha (BJVJ)

THE FIVE zonal Jan Vigyan Jathas, which started on 2 October from Srinagar, Madras, Malda, Solapur and Imphal, converged on Bhopal on 7 November after covering a distance of more than 26,000 km and addressing millions of people at more than 550 stops along the route. Travelling at the rate of about 250 km and giving three performances per day had tired the activists and they looked bedraggled. Though their voices had turned hoarse, there was a gleam in their eyes as they approached Bhopal. The Bharat Jan Vigyan Jatha was truly monumental in its sweep and vision as it attempted to knit the whole country with the sinews of peace and pro-people science.

There were four vans carrying the mobile science exhibitions of the Nehru Science Centre, Bombay, Visvesvaraiya Technical Museum, Bangalore and the National Science Museums from Calcutta and Delhi. Amongst the delegates at Bhopal, the largest contingent came from the Kerala Sastra Sahitya Parishad (KSSP) — one of the oldest and best organized People's Science Movements (PSMs) in the country. Over 750 KSSP activists, all attired in white lungies and white shirts came by a special train. Each of them had individually contributed Rs 500 to defray the transport and other sundry expenses. This certainly demonstrated the organizational capacities of the KSSP.

At Bhopal, all the participants gathered at the Ravindra Bhavan. There was a lot of informal intermingling and exchange of notes as the occasion provided a rare opportunity to meet so many activists from the various PSMs all over the country. At around 11.00 a m the participants divided themselves into seven discussion groups — each headed by a panel of eminent and socially conscious scientist. The groups discussed subjects like "Technology for Self-Reliance", "Health and Drugs", "Education", "Shelter", "Environment and Natural Resources" and "Water Management". The participants were free to choose their own discussion groups depending upon their inclination and interest.

Technology for self-reliance

B M Udgaonkar, chairperson of the Bharat Jan Vigyan Jatha (BJVJ) and a senior professor at the TIFR, decried the reckless opening of the Indian economy for exploitation by the multinationals. He cited two specific examples in support of his arguments. Twenty years back, the late prime minister Indira Gandhi had aked Vikram Sarabhai to suggest areas of high technology in which India could make a debut. One such hi-tech area that was identified was the research and setting up of Earth Satellite Stations. Considerable indigenous R & D went into this sphere and the first such station was successfully set up at Arvi, near Pune, in 1958. But despite considerable indigenous research experience and capability in this field, the government has buckled to multinational pressure and allowed liberal tie-ups with foreign countries in this sector.

The other example was more blatant in castigating the government as it concerned the tie-up in a relatively low technology sector. The pioneering effort of organizations like Kishore Bharati and Eklavya had resulted in the design and evolution of an appropriate, low-cost science teaching kit largely based on local materials. This kit has been continuously tested and upgraded in close collaboration with village children and teachers in Madhya Pradesh over the last 15 years. But despite this, the experts in the NCERT (National Council for Educational Research and Training) have found it necessary to collaborate with Germany to produce science education kits for children of Madhya Pradesh. Soon the NCERT with the "help" of the German "experts" will set up a full-fledged workshop in Bhopal to manufacture these science kits. Udgaonkar said that this anti-national ethos of the government to recklessly import technology can only be broken by sustained pressures from the People's Science Movements.

The panel on education consisted amongst others of M P Parameswaran, convenor of the BJVJ and Anita Rampal from Eklavya. The participants felt that after 40 years of independence the new education policy was abandoning its goal of 100 per cent literacy and universal primary education. This was clearly an abdication of political will. While all over the world, expenditure on education ranged between 6 and 9 per cent of the total government's budgets, India spent a paltry 3 per cent. Even the measly amount was highly skewed in favour of the urban elite and tertiary education sector. The group strongly suggested the use of the mother tongue at the primary school level and a practical approach to the study of mathematics and science.

The group discussion on water management argued that although India receives more rainfall than most other countries of a similar size, the rainfall is unevenly distributed; nearly 50 per cent of the water is lost due to evaporation. The retention of rainwater can be increased by grasslands and forest. The following points were highlighted:

- drought was man-made and was caused by the increased use of ground water.
- afforestion was the best means of fighting drought. Deep-rooted vegetation such as trees is essential.
- water pumps and their utilization of water needed to be socially controlled.
- rational utilization of water could not take place as long as the land holding pattern was not changed.

The rally and the utsav

At around 2.00 in the afternoon all the participants marched in a long rally in

Anita Rampal (Eklavya) and M P Parameswaran (KSSP) at a discussion

Students at the poster exhibition

Bhopal, a distance of 6 km. The route included the Union Carbide factory. The rally stopped at the gates of the factory — the MIC leakage from which had killed around 3,000 people and maimed and decapicitated another two lakh people — and took a solemn oath, "No more Hiroshimas, No more Bhopals".

Low cost science toys stall

The collective open session had 4,000 participants. Each zonal jatha presented one drama skit — the ones they had performed enroute like "Eklavya's Thumb", "Product", Bertolt Brecht's "Learn friends learn" and "The Earth". The open session was addressed by Udgaonkar and Parames waran, and Narendra Sehgal, Director NCSTC, (National Council for Science & Technology Communication) whose department provided the funds for jathas.

Books and toys

The various PSMs had set up stalls to sell their books. The Delhi Science Forum (DSF) had brought out a beautifully illustrated booklet appropriately titled *Darkness of a thousand suns* — an account of the causes, complexion and consequences of the nuclear arms race. The Eklavya stall sold issues of the monthly children's magazine in Hindi, *Chakmak*. They also sold *Khel-Khel Mein* — a book on low-cost science experiments designed as part of the Hoshangabad Science Teaching Programme. *Khel-Khel Mein* sold a record of 1,200 copies in a single day.

One off shoot of the jatha was that some other languages, for instance, *Science Society and Nature* in Malayalam was translated by the KSSP activist K K Krishnakumar into English. The translated version was priced at Rs 5. Another beautiful book which the KSSP should be congratulated for bringing out was Lauri Baker's *How to reduce building costs*.

However, the greatest attraction for children was a stall selling low-cost science teaching aids and toys. It sold a Mariner's telescope — four collapsible tubes with lenses on both ends for Rs 5, a completely dismantable periscope for Rs 5; a hovercraft made out of a balloon and plastic disc with a hole in the centre priced Re 1 sold one thousand pieces within a few hours. The brisk sales of science toys was a revelation of the tremendous potential which concrete "models" hold for interacting with children. It is also a pointer indicating what sort of work needs to be highlighted by the PSMs.

Mutual collaboration should make it possible to set up several local centres for making science toys. Such groups could soon become economically independent and autonomous.

Critical appraisal

A drawback at the Bhopal meeting was the inability of the organizers to convene a meeting of all the five zonal jathas, so that their participants could share their experiences and feelings during the jatha and exchange notes. Such an exercise would have been useful for planning future efforts. However, there was a lot of informal intermingling and the interviews with several activists and outsiders point towards certain salient generalized observations for overall consideration.

1. A modern State with all its complexities is difficult to characterize; the vast Indian State, with 200 years of colonial experience, is even more so. There are contradictions within the State. Often, the left hand of the State does not know what the right arm is doing, or so it appears.

- The Indian State which collects a few thousand crore rupees every year in excise revenue by way of sale of liquor, also gives a few lakh rupees every year to the All Indian Prohibition Council for printing posters for their anti-liquor campaign.
- The same State which supports the Hoshangabad Science Teaching Programme to promote activity based science learning negates this work by collaborating with the Germans for producing science kits.
- The same State whose scientific laboratories are a mockery of people oriented research, also supports science popularization programmes.
- The same State which actively collaborated with Union Carbide at one stage may also find an activity against the multinational at some other stage.

Perhaps, the State machinery is so gargantuan that one bureaucracy does not know what the other is doing. The PSMs should take a cue from the KSSP and endeavour to build their own base amongst the people. This will enable the PSMs to maintain their independence and autonomy and oppose the State, if and when the need arises. Is the Indian State, which spends a staggering rupees 42 crores everyday (or 50 paisa per day per Indian citizen on armaments and war machinery), a pro-people's State?

2. The participation of women in the jatha was very marginal. Less than 5 per cent of the 750 KSSP activists coming from Kerala were women. If women constitute half the people of the country, the participation of women and the inclusion of the feminist viewpoint on S&T is essential to humanize the movement.

3. The programmes during the BJVJ were dependent on the composition and savvy of the local committees. About 60 per cent of the programmes were hosted by some college or educational institution, which assured a captive audience of students and children to the exclusion of the toiling people. At places where the programmes were held at the market place or the city square, the participation of the common people was much more.

4. The BJVJ attempted to collaborate with groups belonging to a wide array of political persuasions but it appears that a few groups with a different political hue were not accommodated or were outright rejected. Irrespective of political tendencies, PSMs should try and broaden their overlap with other groups.

5. The centralized training workshops for theatre and science toys resulted in certain standard stereotypes: With little room left for incorporating local forms and innovating with local specificities, the same set of skits were performed all over the country without taking into cognizance the local conditions and demands. There was little flexibility, for instance, to improvize a skit on "drought" which severely afflicted the states of Gujarat and Rajasthan.

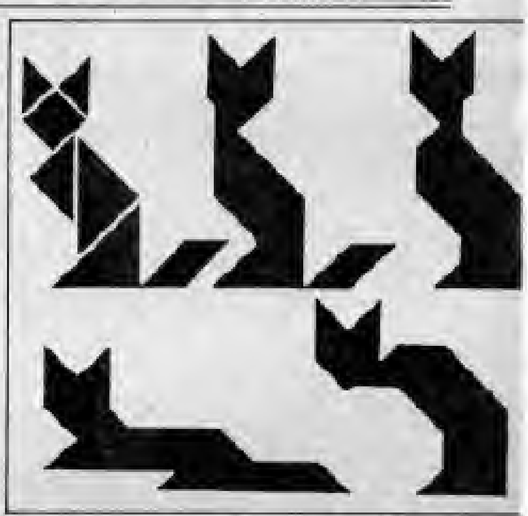
At no time have so many PSMs come together for a single programme. This intense human to human contact will enable the PSMs to come closer to each other and learn from each other's experiences.

ARVIND GUPTA

Tangram

TANGRAM IS a Chinese puzzle believed to be more than a 1,000 years old. No one knows who its inventor was. In China it is popularly known as the "Seven Boards of Cunning". Even today this puzzle remains unmatched for its simplicity, possibilities and sheer brilliance.

The puzzle resembles the western jigsaw puzzle, but it differs from the jigsaw in that it always has the same number of pieces, which can be fitted together in different ways to make a number of shapes. The seven pieces are formed by cutting a square in a certain way. The size of the square is immaterial. It is only the relative proportions of the pieces that matter. The seven pieces consist of (1) a pair of big triangles, (2) a pair of small triangles, (3) a middle sized triangle, (4) a square and (5) a parallelogram. All the seven pieces must be used in each case to construct the figures. The figures could be geometrical (such as a triangle, trapezium or parallelogram); or representational (human figures running, sitting, falling, playing, dancing, reading, man on a horseback, birds, animals, bridges, boats, houses, etc).



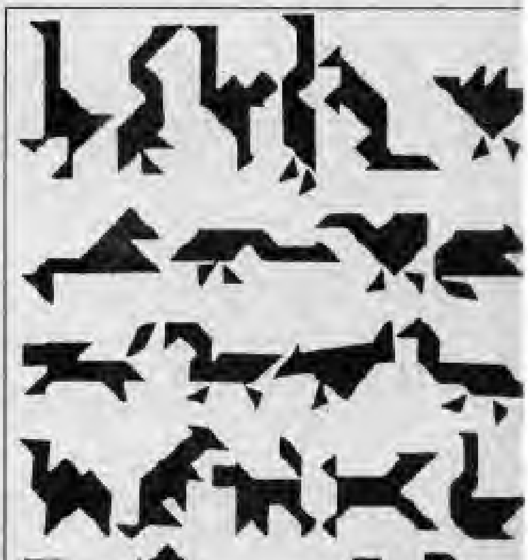
Conservation of area

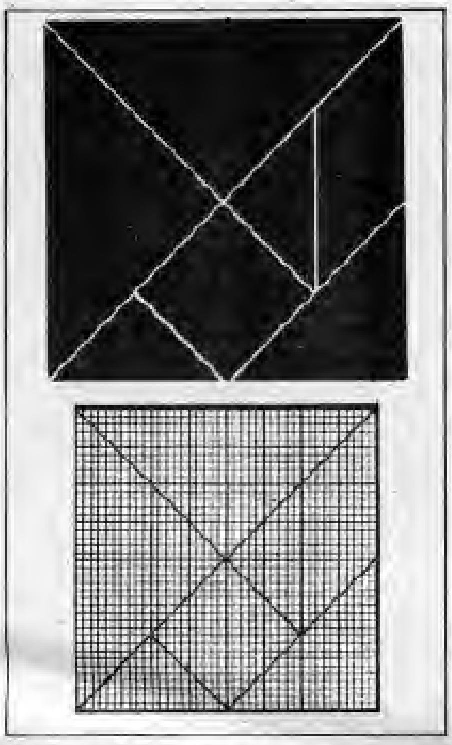
It is possible to make several thousand figures using all the seven tangram pieces in each case. Some of the human and animal shapes are easy to construct because in these tangram pieces can be easily "figured out" — the two small triangles for the feet, the square for the head, etc. On the contrary, some of the abstract geometric shapes like hexagons, parallelograms, are more difficult to make. This is because it is difficult to isolate any individual tangram piece in these geometric shapes. For instance, anyone who has not seen the tangram being cut would be hard put to assemble the square out of the seven pieces.

Because all the seven pieces have to be used in each case, so the area of each figure remains the same. This beautifully illustrates the principle of conservation of area. Also, in the process of assembling the seven pieces into meaningful formats one gets a tremendous feel for ratios and proportions.

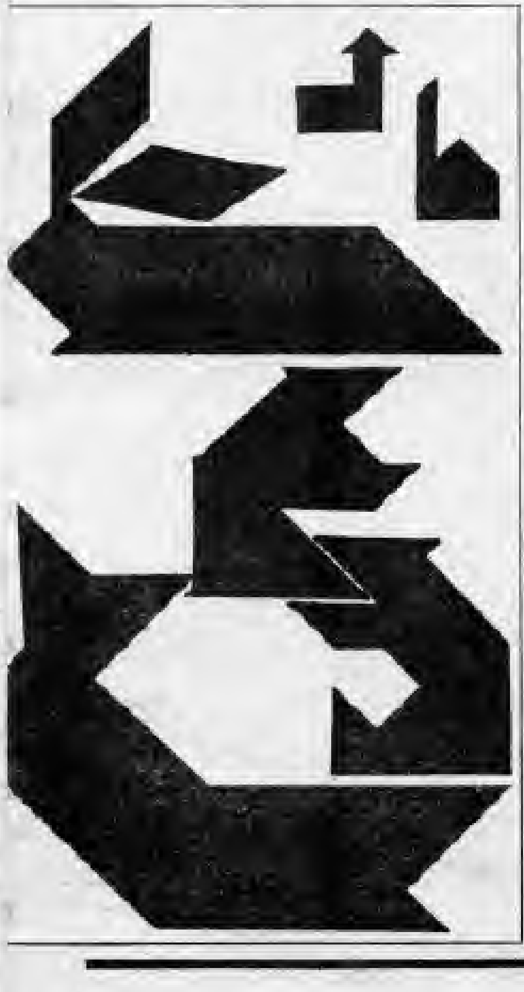
Make your own tangram

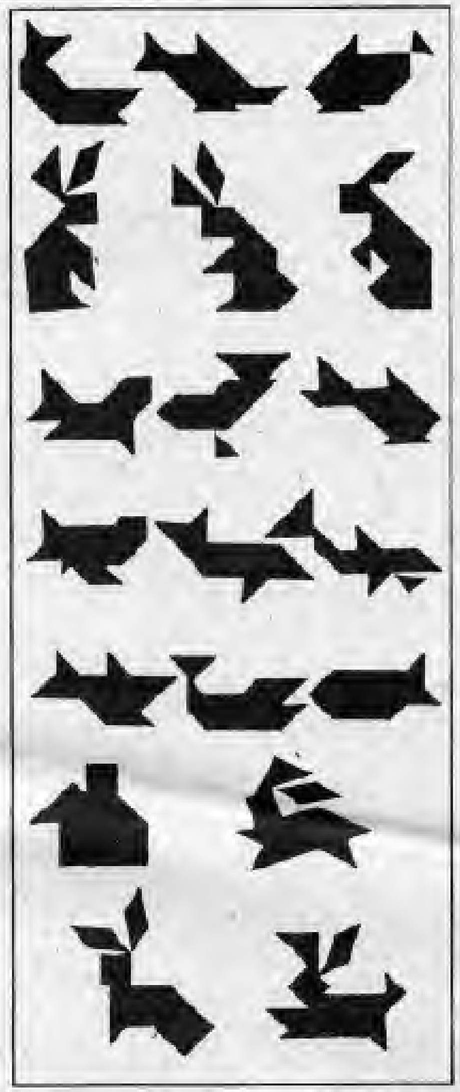
It's simple. Mark out the tangram pattern on a graph paper or, simpler still, on a square grid copy used for school arithmetic. A 100-mm square tangram is quite easy to handle. Mark the outer square on the grid along with the seven shapes. Stick this paper on a thick cardboard and cut all the seven pieces with a sharp knife. All the pieces are then coloured black on both the sides. As cardboard tends to fray and wear after some use, a more appropriate material for making tangram is the "rubber" used on chappal top, just over the sole. It is called "bunbur" by the cobblers. This rubber comes in different colours in thicknesses of 3 and 4 mm. It is plain on both sides. It is workable and easily cut with a shoemaker's knife. A 100-mm square of bunbur costs around Rs 1.25 only.





Tangram is a 1000-year old Chinese puzzle. The game consists of seven pieces, formed by cutting a square in a certain way. Using all the seven pieces of the square in each case, make the following shapes. Only the outlines are being given. You have to figure out how the seven pieces have been put together in each case.





A few tangram figures shown will give you a glimpse of the versatality and possibilities of the tangram. In each case only the outline has been given and you have to figure out how the seven pieces have been put together. Tangrams will present a real and pleasurable challenge to your skill and imagination. Tangram is one puzzle which transcends barriers of literacy and age. It will enthuse one and all — from the schoolboy to the scholar. Artists have used tangram for designing trademarks and symbols. It gives excellent practice as an exercise in concentration or as a training in the understanding of shapes. Try making your own figures with the seven shapes. Tangram is simply enchanting: no wonder Napoleon whiled away the monotonous years of his exile playing with the tangram.

For more info, refer to *Tangram* by Joost Elffers (Penguin Books)

ARVIND GUPTA

Mr Gupta is an IIT-Kanpur trained engineer. He has been associated with several educational and development groups and has written and translated many popular science books and articles.

OH, THESE SCIENTISTS!

George Abell will be long remembered for a very unusual distinction. He figures in the *Guiness book of world records*:

> Eponymous record. The largest object to which a human name is attached is a supercluster of galaxies known as Abell 7, after the astronomer Dr George O Abell of the University of California. The group of clusters has an estimated dimension of 300,000 light years and was announced in 1961.

* * *

When Wolfang Pauli discovered the "exclusion principle" in 1925, the world of quantum physics was in constant ferment with the flow of new discoveries. According to this principle, two electrons cannot be in the same place at the same time — they exclude each other. If you force them together, they repel each other. This repulsive force, called the "exchange force", has no analogue in classical physics and can be understood only in a quantum world. But this world was becoming more and more difficult to fully comprehend. So much so that it led Pauli to exclaim, "Physics is decidedly confused at the moment; in any event, it is much too difficult for me, and I wish I had never heard of it."

* * *

When Werner Heisenberg appeared for his degree, he was required to take an oral examination. He was asked to calculate the resolving power of a microscope — an elementary calculation in optics. He couldn't, because he didn't know the physical properties involved. Heisenberg did get his degree, but was denied full honours and admonished to study optics.

Heisenberg later discovered the "uncertainty principle", a profound feature of quantum mechanics not found in Newtonian mechanics. It states that certain pairs of physical variables — such as momentum and position of a particle — cannot be simultaneously measured with precision; one can only obtain a probability distribution of these measurements. And Heisenberg illustrated this remarkable principle by considering the resolving power of a microscope — the very problem he stumbled over for his orals.

Slinky

FROM THE thousands of science experiments with waves, we know that they are either transverse or longitudinal. Here we'll explore these different waves.

String waves

Tie a string or a clothes-line about 20 ft (about 6 metres) long to a door knob or a tree. Hold the free end of the rope in your hand so that it is almost parallel to the floor. Move the rope up and down, first slowly and then rapidly. Though the hand moves up and down the string waves move forward, that is, in a direction perpendicular to the direction of disturbance. Fold an old postcard to a V-shape and put it on the string. Now, move the string up and down to produce a series of waves. What happens to the postcard as the waves pass under it? Can you get the waves to travel along the rope without the postcard falling off?

Water waves

Let's now examine the motion of water waves. Imagine a stone falling in a pool of still water. The weight of the stone pushes down the water with which it comes into contact and a depression is created. But water is almost incompressible, so room must be made for the water that is pushed downward's. This can only be done by raising the water in the immediate neighbourhood of the fallen stone, so the central depression is surrounded by a ring of raised water.

The ring of raised water falls back under the pull of gravity and its weight acts like the original weight of the stone. It pushes the water underneath downwards and throws up a wider ring of water a bit further away from the original centre of disturbance. This process continues and the concentric ripples move further and further away from the centre. It is important to realize that water is moving up and down only. The disturbance is propagated outward across the surface of the water, and it appears as if the water is moving outward; however, it is not. Only the disturbance is moving out. A cork floating on water that has been disturbed into ripples will rise and fall with the rise and fall of the water it rests on, but the moving water ripples will not carry the cork with it.

Transverse waves

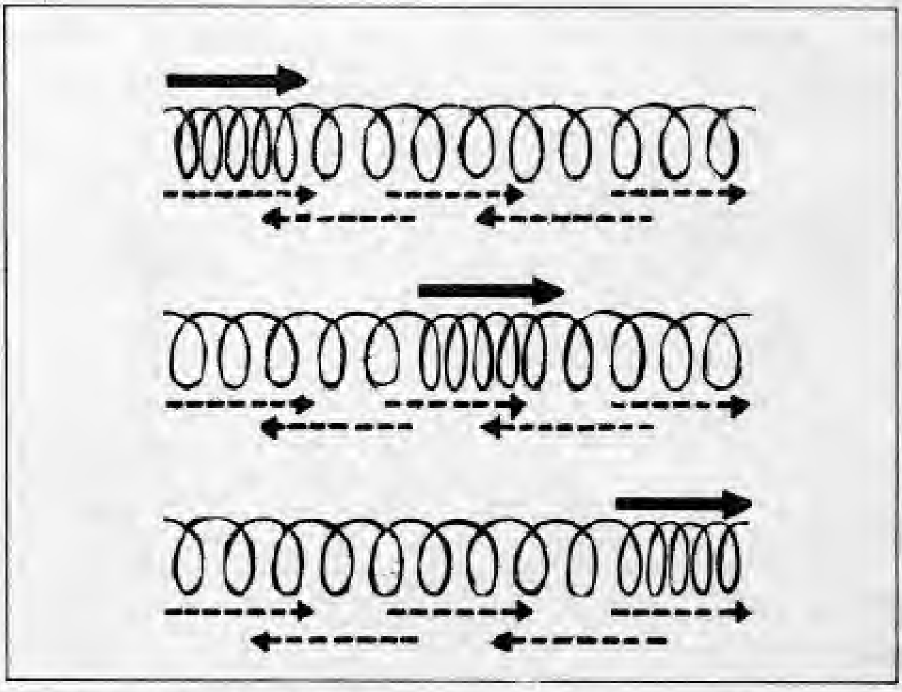
A wave like the string wave or the water wave in which the motion of each part in one direction (up and down in this case) and the direction of propagation of the disturbance is at right angles to the direction (outwards across the string or the water surface in this case) is called a transverse wave. Transverse comes from Latin; it means "lying across"

Metallic slinky

Long metallic springs have been sold abroad for a long time (Fig 1). The metallic slinky is now being produced in India and is available for around Rs 20 Spring coils that move back and forth have produced many hours of pleasure for children. The slinky has also been used to learn more about waves. If the free ends of such a slinky are held in the two hands, their metallic coils pour from one hand into the other as if it was a metallic siphon. A metal slinky can also be made to climb down stairs. Its motions are extremely intriguing.

Longitudinal waves

Another kind of wave motion is illustrated in the vibrations of a tuning fork. The prongs of a tuning fork move left, right, left, again in a rapid periodic motion. As it moves, it creates waves of alternate compression and rarefaction, the individual molecules of air move in one direction when compressed and in the reverse direction when rarefied. The volumes of compression and rarefaction move outwards and are propagated in a direction parallel to the back and forth motion of the molecules. Such a wave, in which the particles move parallel to the propagation rather than perpendicular, is a longitudinal wave or a compression wave. Sound travels in longitudinal waves.



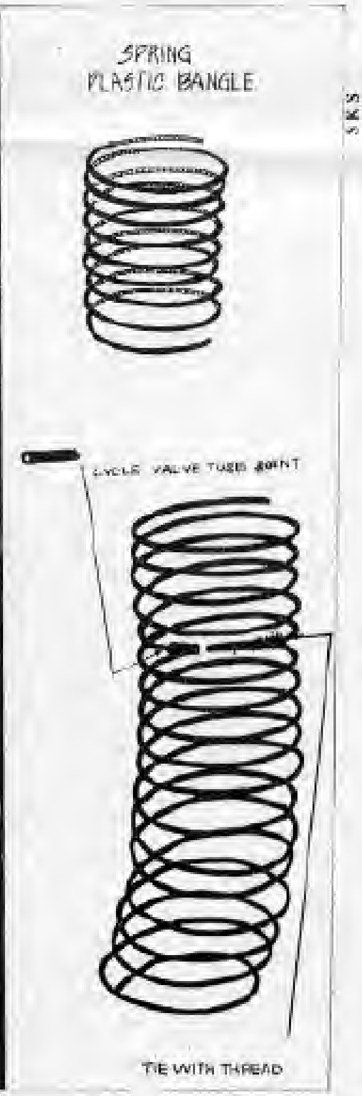
Plastic bangle slinky

Coil plastic bangles are sold as trinkets in villages. Apart from bright colours they also come in four different diameters. Each spring bangle has 24 coils. They cost about Re 1 each. Couple the ends of three such plastic spring bangles with the help of two bits of cycle valve tube. The end coils of adjacent bangles are joined with a thread (Fig 2).

This long spring bangle makes a delightful slinky. Hold one end of this slinky vertically and give the hanging coil a jerk. The whole spring bobs up and down and starts oscillating. Slowly, because of friction, the successive oscillations become smaller and ultimately die out. This is a beautiful demonstration of damped oscillations.

Fasten one end of the coiled springs to the leg of a desk or a chair and stretch the spring along the floor (Fig 3). Jerk the free end of the spring. A disturbance is created which travels along the spring, and returns after reaching the chair end. It's like sending a message and getting a reply back. It's also akin to an incident ray of light striking a normal and returning back as a reflected ray. Do the slinky coils move at right angles to the disturbance that goes down the length of the spring? No. The direction of motion of the disturbance is parallel to the back and forth motion that causes it. It is different from the string waves and the water waves.

Now hold both the free ends of the bangle slinky and jerk them inwards. Waves emanate from both ends and collide in the middle, graphically demonstrating the interference of waves.



If one end of the bangle slinky is jerked on a smooth floor it moves like a slithery caterpillar.

Each spring bangle makes a low-rigidity spring. It can be used to perform many experiments where a low-rigidity spring is required. Most of the springs used in ordinary bicycles are so rigid that it takes several kilograms of load before one registers an appreciable extension. Hang a bangle spring from a nail and wedge an old postcard between its lower coils.

The postcard acts both as a pan as well as an extension indicator. Now, keep adding 25 paise coins (weighing 2.5 g each) to the postcard pan and measure the extension. A plot of the load versus the extension would give a straight line indicating that the spring was well within elastic limits.

ARVIND GUPTA

Mr Gupta, an IIT-trained engineer, has been associated with many educational groups. He has written several popular science books and articles, especially for children.

INDIAN EXPRESS 7·1·87

Cheap way to teach science

Express News Service

Bangalore, Jan. 6: The principles of geometry, molecular structure [illegible]ethane and certain basic ideas [illegible] structural engineering were realistically demonstrated with the help of match sticks, marbles and cheap rubber tubes by a young engineer at the Indian Science Congress here on Tuesday.

At a special session for young scientists, Mr. Arvind Gupta demonstrated inexpensive methods of developing teaching aids for rural children with the help of easily available materials. "Children just love these games that teach them that science is around them, everywhere," he said. "Aushangabad science" from Madhya Pradesh, nearly 14 years old, is gaining popularity in 13 districts of MP.

The method is easy to understand and based on sound scientific principles. With the help of valve tubes available in any cycle shop and match sticks with heads scrap[illegible] off, Mr. Gupta built simple geometric figures with flexible joints.

"With five such small rubber tubes fitting an equal number of sticks you make a pentagon. Since the joints are flexible you make different shapes of pentagons. With four sticks you make a square that can easily convert to a rhombus of various angles. When you come to a triangle you stop. Although flexible, the joints do not bend"

By this simple demonstration Mr. Gupta had explained the entire principle of triangulation used

Arvind Gupta

in structural engineering to build trusses for bridges, hangers and other structures requiring rigidity. All linkages are constructed in such a way that they form triangles.

"My engineering friends, after seeing these demonstrations, have told me that it was never so clear to them before," Mr. Gupta told ENS later. A number of fascinating models have been developed by his colleagues of the "Aushangabad science" that was originally developed by two eminent educationists, Dr. Anil Satgopal and Dr. Sudarshna Kapoor, in 1972.

With two injection tubes Mr. Gupta had made an hourglass. The rubber caps of the bottles have been pasted with solution back-to-back, a hole has been made with a big thorn and the orifice has been made uniform by inserting a piece of ordinary refill in them. "By putting the right amount of sand in the bottles you can time it exactly for a minute or two," he said.

Mr. Gupta has alongside made small wooden cubes from electric beading used in all homes and with letters painted on the cubes a boggle puzzle is ready. Each boggle unit with the hour glass will not cost more than Rs. 2.50. "The same thing from one of our popular toy companies costs about Rs. 40. Where can Indian children, barring the rich minority, get such money?" he asked.

Tangram, the 1000-year-old Chinese puzzle in which children make animals in several postures from seven uneven pieces of a square, has been created with a sheet of cobbler's rubber. Photocopy sets of diagrams are enclosed with the rubber pieces and the whole thing is sold for Rs. 1.50. "Our rubber is soft and unbreakable unlike the commercial puzzle available for Rs. 80".

Gear mechanisms from soda bottles, tipper trucks from matchboxes, and toy trains with button wheels, made from battery cells, are part of Aushangabad science. "It is fun and very practical," Mr. Gupta said.

Unfortunately, tradition has still not accepted the unconventional and useful methods of this science. "We are getting children at the levels of sixth and seventh standards so far to demonstrate the methods but it is too late by then. Only recently we have started on children at lower levels," he said.

Rules of thumb

THERE'S THIS story of a village mother-in-law who had three daughters-in-law. And like most folk lore mothers-in-law, this one also took life easy, assigning chores to the younger women. And the chores were distributed among the three quite fairly. Only in dire circumstances did the mother-in-law share their burden.

The task of cooking was assigned to the petite dainty daughter-in-law. One day, while the lady in charge of the kitchen was away visiting her parents, a hoard of guests dropped in and it fell to the youngest daughter-in-law to cook for them. On instructions from the lady of the house, she added two handfuls of salt to the curry. It became uneatable — just too salty. Thinking that she had done it out of spite, the old lady assigned the job to the other daughter-in-law the next day. The result was even worse. Meanwhile, the petite one returned and conditions improved.

After the guests had left, the mother-in-law admonished the two awful cooks. But they pleaded "We only followed your instructions". They had. So what exactly went wrong. The answer's simple: the amount of salt in the "handful" of the three young women varied greatly. Maybe the story's an exaggeration, but don't folklores thrive on that?

If you visit villages even today measurements are done by approximate means. A villager many check the length of a piece of cloth by stretching it from the tip of her nose to the end of her extended hand or from the tip of her finger till her elbow. Small lengths, might be told as number of finger breadths; weights may be told in the form of "as much as that vessel filled with water", a house, field or a depth of a pond etc may be described as "so many man lengths, or bullock lengths".

Measures have been used loosely and where there has been no need for high accuracy they have served a purpose. Why, a friend in Bombay who had bought a new flat described it to be thus "Twenty persons can sit comfortably in the living room so you can judge its area"; I was foxed but my other friend, also from Bombay, seemed to understand it perfectly.

When one uses such subjective forms of measurements there is always the danger of errors. So one has to be a little more specific. That's where standardized measures come in. One square cm is the same no matter who marks it.

But one can't always carry around a measuring device: some people do. There are some easy ways of measuring using everyday objects. The secret here, however, is that these objects are standardized against known meausres. There are several thumb rules for this.

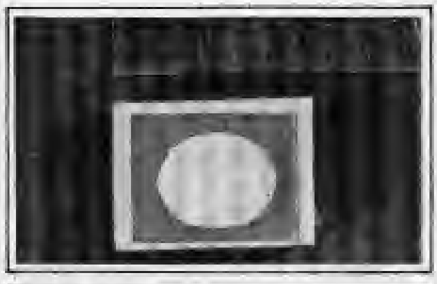
Thumb rules are ready reckoners which enable you to compare and crosscheck your estimates with ease. One such ready reckoner is the matchbox, a low-cost universally available item of everyday useage. Millions of matchboxes are manufactured per day in factories. Because the matchbox is mass produced and factory made, its size and dimensions conform to certain standards. The same is true of many other objects in daily use. Let's discover some fascinating facets of this most familiar cuboid-the matchbox.

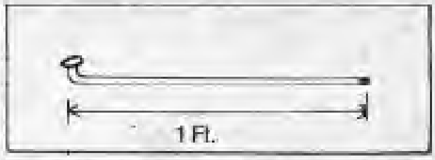
The length of a matchbox is always 5 cm (2 inches) and so it can be used for estimating length. The length of six matchboxes kept end-to-end equals 30 cm or almost one foot. Some other objects can also be used as good estimates for measurement of length. The postcard, for instance, is always 14 cm long and 9 cm broad. A ballpen plastic refill tube has an outer diameter of 3 mm. Matchsticks have a square cross-section. Each side of this square measures 2 mm. Normal bicycle spokes are 30 cm (or one foot) long. Normal bricks are 9 inch long (22.05 cm) Coins have standard dimensions. They can be used as fairly accurate measures to estimate length.

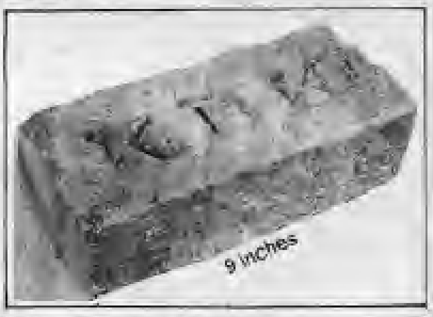
Thus even if you don't have a ruler at hand, you can always use some matchboxes, coins etc to estimate length

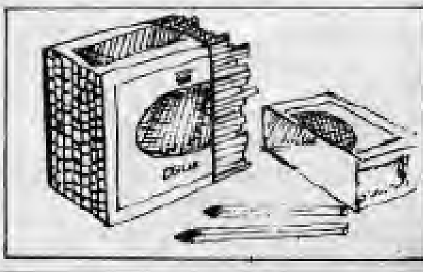
Try to guess lengths by looking at the object. Before measuring, first make a mental estimate of the length of the object. Then measure it either with a scale or with some improvised thing whose length you already know. Compare the difference between your guess and the actual measured length. This way you can refine your estimations; you can even use your hand. You could, measure the length of your handspan and use it for approximating different lengths. And now, one for the road. How much distance do you cover in one step while walking? You can use this estimate for approximating long distances like how far is it from the bus stop to your house.

A matchbox has three distinct surfaces — the label surface (A), the strike surface (B) and the drawer surface (C). Why is









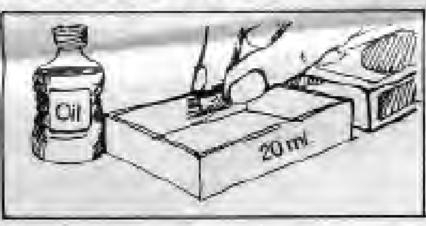
(A) bigger than (B), when both of them share a common length? Why is (B) bigger than (C), when both of them share a common breadth? Area depends on both length and breadth, and a change in either of these dimensions will lead to a change in area.

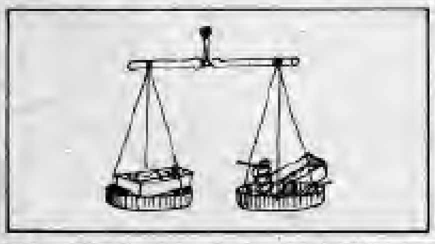
How can you find the area of the matchbox shell in which the drawer fits? One simple way, of course, is to measure the length and breadth and then to multiply them. There is, however, a very interesting way of finding the area of the matchbox shell. You've just seen that the cross-section of matchsticks is 2 mm × 2 mm. Matchsticks can be used as standard "bricks", for measuring area. Pack burnt matchstick "bricks" in the outer shell of a matchbox, to construct a wall. The area of each "brick" is a standard and is already known. By counting the total number of matchstick "bricks" used, you can estimate the area of the matchbox shell. A large area is composed of many small areas. Obvious, isn't it?

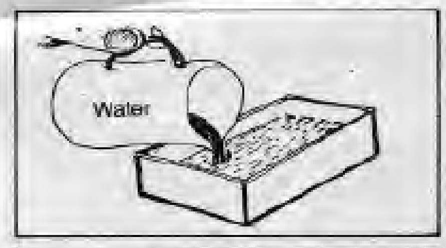
But why is it useful to know that? Well, if you know the area of a unit component, you could calculate the area of the whole. For example, by counting the tiles in a room you could tell its area. And in case of an irregular shape, you could divide up the space into easily measurable dimensions and add up the areas of several bits to get the area of the whole.

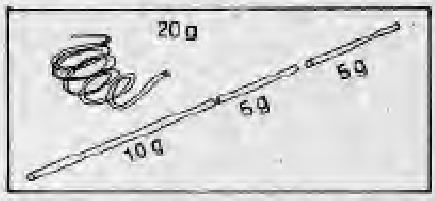
The two dimensional graph is an abstraction. But the square matchsticks snugged together in the matchbox shell can give a concrete feel of the graph paper.

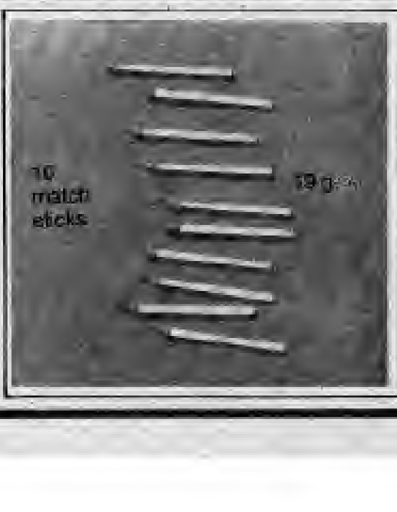
Dip a little cotton ball in oil and rub it on the matchbox drawer. Soon the wood and the paper of the matchbox drawer will absorb the oil. Dry the drawer in the sun. By oiling, the drawer becomes waterproof. This drawer when filled with water holds approximately 20 millilitres (ml) of water. (The drawers' capacity is a good estimate for measuring 20 ml.) You can use this as a rough standard for measuring volume. To make a volume measuring device stick a thin strip of white paper along the length of a bottle. (It would be nice if you could get a tall thin bottle of more or less uniform diameter.) Now, fill up a matchbox drawer level full with water and pour it in the bottle. Indicate the water level in the bottle by marking a line on the paper. This line becomes the 20 ml mark. Add more drawers full of water in the bottle, each time marking the levels: 40 ml, 60 ml, 80 ml, 100 ml etc on the paper strip. You can put mid points between these graduations to indicate 10 ml difference marks. This graduated bottle becomes a measuring cylinder for liquids. If you fill the bottle up to the 100 ml mark, and then pour it out in a bucket and repeat it ten times, you can have a measure for 1,000 ml or one litre. (A milk bottle generally holds 500 ml (½ litre) of liquid.











Make a simple balance using leaf cups or boot polish tins for the pans. The pans can be suspended with strings and then hung on either side of a uniform stick. Ensure that the balance point is equidistant from the two pans. Only then will the balance weigh truly. If the beam isn't properly balanced, gently pour sand in the raised pan until the beam becomes horizontal. Now, keep a matchbox drawer on each of the pans. As the drawers have the same weight the beam will remain balanced. Fill the left hand drawer with water up to the brim. You already know that the drawer holds 20 ml of water. And 1 ml of water weights 1 g — the density of water. So, 20 ml of water will weigh 20g. It amounts to putting a 20g weight in the left hand pan. Place an appropriate length of any junk wire in the right hand pan to balance the beam. This wire shall now weigh 20 g. Straighten out the wire and cut it into half and quarter lengths to make 10g and 5 g weights. You can similarly make 50g and other weights.

We all carry standard weights in the form of coins in our pocket. You must often have seen shopkeepers using coins to weigh small quantities of material. The approximate weights of some of the coins are:

One rupee coin (old)	8 g
One rupee coin (new)	6 g
50 paise coin	5 g
25 paise coin	2.5 g
5 paise coin (aluminium)	1.5 g

Thus two, twenty-five paise coins equals a fifty paise coin not only in monetary value, but also in weight. This is a very interesting relationship.

A sealed, brand new matchbox is a good estimate for 10 g; 50 unburnt matchsticks weigh approximately 5 g. Thus, 10 matchsticks are a good estimate for 1 g, and one single unburnt matchstick a very good estimate for 0.1 g.

After having learnt to make measuring devices and measure, you are probably on the right way of thinking quantitatively. And to think of it we still have measures like Manday — the work a man can do in one day.

ARVIND GUPTA

Mr Gupta, an electrical engineer, has been involved with People's Science Movements. At present he is on a DST fellowship writing a book on matchstick meccano and other science experiments.